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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Jae-Yoel Kim et al. | Examiner: Torres, Joseph D.

Serial No.: 09/879,688 | Group Art Unit: 2133

Filed: June 12, 2001 | Docket: 678-693 (P9800)

For: **APPARATUS AND METHOD FOR ENCODING AND DECODING TFCI IN A MOBILE COMMUNICATION SYSTEM** | Dated: June 8, 2007

Mail Stop Appeal Brief-Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313

TRANSMITTAL OF APPELLANTS' BRIEF ON APPEAL

Sir:

Enclosed please find APPELLANTS' BRIEF.

Also enclosed is a check in the amount of $500.00 to cover the appeal fee.

If the enclosed check is insufficient for any reason or becomes detached, please charge the required fee under 37 C.F.R. §1.17 to Deposit Account No. 50-4053. Also, in the event any additional extensions of time are required, please treat this paper as a petition to extend the time as required and charge Deposit Account No. 50-4053. TWO COPIES OF THIS SHEET ARE ENCLOSED.

Respectfully submitted,

Paul J. Farrell
Reg. No.: 33,494
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CERTIFICATE OF MAILING 37 C.F.R. §1.8(a)

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Dated: June 8, 2007

Michael J. Musella

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Dated: June 8, 2007

Michael J. Musella

Attorney Docket No.: 678-693 (P9800)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

APPLICANT(S): Jae-Yoel Kim et al.

GROUP ART UNIT: 2133

SERIAL NO.: 09/879,688

EXAMINER: Torres, Joseph D.

FILING DATE: June 12, 2001

DATED: June 8, 2007

FOR: APPARATUS AND METHOD FOR ENCODING AND DECODING TFCI IN A MOBILE COMMUNICATION SYSTEM

Mail Stop Appeal Brief-Patents
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P.O. Box 1450
Alexandria, VA 22313-1450

APPELLANTS' BRIEF ON APPEAL

REAL PARTY IN INTEREST

The real party in interest is Samsung Electronics Co, Ltd, the assignee of the subject application, having an office at 416, Maetan-dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, Republic of Korea.

RELATED APPEALS AND INTERFERENCES

To the best of Appellants' knowledge and belief, there are no currently pending related appeals, interferences or judicial proceedings.

CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8 (a)

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail, postpaid in an envelope, addressed to the: Commissioner for Patents, Alexandria, VA 22313-1450, Mail Stop Appeal Brief-Patents on June 8, 2007.

Dated: June 8, 2007

Michael J. Musella

STATUS OF CLAIMS

The original application filed on June 12, 2001 contained Claims 1-27. In a Response to Restriction Requirement filed February 23, 2004, Claims 8, 9, 19 and 20 were provisionally elected, without prejudice and with traverse, Claims 1, 2, 4-6, 8, 10-12, 14-17, 19, 21-23 and 25-27 were amended, and new Claims 28-31 were added. In a Response to Restriction Requirement filed April 19, 2004[1], Claims 1-7, 14-18 and 25 were provisionally elected, again without prejudice and again with traverse, Claim 31 was amended, and Claims 10-13, 21-24 and 26-28 were cancelled.[2] In a Response filed October 19, 2004, Claims 25 and 31 were amended, Claims 1-7 and 14-18 were cancelled, and new Claims 32-38 were added. In a Response filed October 13, 2005, Claims 8, 19, 25 and 29 were amended. In a Response filed May 12, 2006, Claims 8, 19, 25, 29-31, 33 and 34 were amended, and new Claims 39-44 were added. In a Response filed November 28, 2006, Claims 8 and 19 were amended.

Thus, 8, 9, 19, 20, 25 and 29-44 are pending in the Appeal. Claims 8, 19, 25 and 29 are in independent form. Claims 32, 35 and 37 have been found to contain allowable subject matter. For the purposes of this appeal, Claims 8, 19 and 41-44 stand or fall together, Claims 9, 20, 36 and 38 stand or fall together, and Claims 25, 29, 30, 31, 33, 34, 39 and 40 stand or fall together.

STATUS OF AMENDMENTS

To date, all of the amendments to the claims have been entered. Thus, the Appendix to this Appeal Brief includes Claims 8, 9, 19, 20, 25 and 29-44, of which the status of Claims 8, 19, 25 and 29-44 is indicated as "Previously Presented", and the status of Claims 9 and 20 is indicated as "Original".

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[1] Following an Examiner's Interview conducted on March 10, 2004, a second Restriction Requirement issued on March 17, 2004 by the Examiner. Although an oral election was made during the Examiner's Interview, the Examiner issued the Restriction Requirement "because of the complexity of the claim language and because of the changes in the claim groupings after careful analysis, the Examiner determined that a written Restriction was more appropriate." See Examiner-Initiated Interview Summary attached to the Restriction Requirement dated March 17, 2004.

SUMMARY OF CLAIMED SUBJECT MATTER

The invention as recited in Claim 8 relates to an apparatus for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) into a sequence of 48 symbols in an NB-TDD mobile communication system, the apparatus for encoding having at least an orthogonal sequence generator, a mask sequence generator, and adder, and a puncturer.

The apparatus includes an orthogonal sequence generator for creating a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI (Specification at page 16, lines 20-21, FIG. 7A).[3]

The apparatus further includes a mask sequence generator for creating a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI (Specification at page 17, lines 28-29, FIG. 7A).

The apparatus also includes an adder for adding a biorthogonal sequence from the orthogonal sequence generator and a mask sequence from the mask sequence generator (Specification at page 18, lines 16-17, FIG. 7A).

The apparatus still further includes a puncturer for performing puncturing on sequences output from the adder so as to output the sequence of 48 symbols (Specification at page 18, lines 17-19, FIG. 7A).

The invention as recited in Claim 9 relates to an apparatus as claimed in claim 8, wherein the puncturer performs puncturing according to one of following puncturing patterns:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

---

[2] In an Office Action dated May 19, 2004, the Examiner stated that the second restriction was overcome by the arguments presented by the Appellants in the Response filed April 19, 2004.

[3] Although a citation for each feature of the claims is provided herein, Applicants do not concede the fact that support may be found elsewhere in the written description.

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at pages 18-19).

The invention as recited in Claim 19 relates to a method for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each of successively transmitted frames into a sequence of 48 symbols in an NB-TDD mobile communication system.

The method includes creating in an orthogonal sequence generator a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI (Specification at page 16, lines 20-21).

The method further includes creating in a mask sequence generator a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI (Specification at page 17, lines 28-29).

The method further includes adding in an adder the selected biorthogonal sequence and the mask sequence (Specification at page 18, lines 28-29).

The method still further includes performing puncturing in a puncturer on sequences output from the adder so as to output the sequence of 48 symbols (Specification at page 18, lines 17-19).

The invention as recited in Claim 20 relates to a method as claimed in claim 19, wherein the puncturing is performed according to one of following puncturing patterns:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at pages 18-19).

The invention as recited in Claim 25 relates to an apparatus for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each 48 symbols in a mobile communication system, the apparatus for encoding having at least a second order Reed Muller code generator and a puncturer.

The apparatus includes a (64,10) second order Reed Muller code generator for generating 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits (Specification at page 8, lines 1-24).

The apparatus further includes a puncturer for puncturing 16 symbols out of the 64 coded symbols wherein puncturing positions of the 16 symbols are as follows

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at page 18).

The invention as recited in Claim 36 relates to an apparatus as claimed in claim 25, wherein the puncturer performs puncturing according to any one of puncturing patterns given below:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at page 18-19).

The invention as recited in Claim 29 relates to a method for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each 48 symbols in an NB-TDD mobile communication system.

The method includes second order Reed Muller coding for generating in a second order Reed Muller code generator 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits (Specification at page 8, lines 1-24).

The method further includes generating 48 symbols by puncturing 16 symbols out of the 64 coded symbols wherein puncturing positions of the 16 symbols in a puncturer are as follows:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at page 18).

The invention as recited in Claim 38 relates to a method as claimed in claim 29, wherein the puncturing is performed according to any one of puncturing patterns given below:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61} (Specification at pages 18-19).

GROUNDS FOR REJECTION TO BE REVIEWED ON APPEAL

Whether Claims 8 and 19 under 35 U.S.C. §103(a) are unpatentable over Citation #4 ("Text Proposal Regarding TFCI Coding For FDD", TSGR1#7(99)D69, August 30 - September 3, 1999) in view of Wicker (Stephen B. Wicker, Error Control Systems for Digital Communication and Storage, Prentice-Hall, 1996, pages 149-155).

Whether Claims 9 and 20 under 35 U.S.C. §103(a) are unpatentable over Citation #4 and

Wicker in view of Tong et al. (U.S. Patent 6,744,744).

Whether Claims 25, 29, 36 and 38-40 under 35 U.S.C. §103(a) are unpatentable over Citation #4 and Wicker, in view of Tong et al. and Citation #7 ("Harmonization Impact On TFCI And New Optimal Coding For Extended TFCI With Almost No Complexity Increase", TSGR#6(99)970, July 13-16, 1999).

Whether Claims 30, 31, 33, 34 and 41-44 under 35 U.S.C. §103(a) are unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7.

ARGUMENT

The Examiner rejected Claims 8 and 19 under 35 U.S.C. §103(a) as being unpatentable over Citation #4 in view of Wicker. The Examiner rejected Claims 9 and 20 under 35 U.S.C. §103(a) as being unpatentable over Citation #4 and Wicker in view of Tong et al. The Examiner rejected Claims 25 and 29 under 35 U.S.C. §103(a) as being unpatentable over Citation #4 and Wicker, in view of Tong et al. and Citation #7.

1. Appellants' response to statements contained in the final Office Action dated January 31, 2007

Appellants' respectfully submit the following arguments in rebuttal to statements contained in the Response to Arguments section of the Office Action dated January 31, 2007 and marked "Final" by the Examiner.[4]

1A. Appellants' respectfully submit that the Examiner has not properly presented a rejection of independent Claims 8 and 19

The Examiner sets forth in the present and Final Office Action an alleged rejection of independent Claims 8 and 19.[5] The Examiner states that Claims 8 and 19 are rejected under §103(a), citing two (2) references and directing the Appellants to a non-Final Action dated August 28, 2006.

[4] See Office Action dated January 31, 2007, at pages 2-6, paragraph no. 2.
[5] See Office Action dated January 31, 2007, at page 7, paragraph no. 3.

At this time a brief review of the file history is required.[6]

On January 19, 2006 the Examiner issued an Office Action containing a rejection under §103(a) of Claims 8 and 19.[7] In a subsequent Response filed May 12, 2006, Appellants submitted arguments directed to the merits of the rejections.[8] On June 29, 2006 the Examiner issued an Office Action containing a statement that the arguments contained in the May 2006 were fully considered but found not persuasive.[9] Also in the June 2006 Office Action, the Examiner set forth a rejection under §103(a) of Claims 8 and 19, and directed the Appellant to the non-Final Action of January 2006.[10] In August 2006 three interviews were conducted between Appellants' representative, and either the Examiner or the Examiner's supervisor, one result of which was the withdrawal of the June 2006 Office Action. On August 28, 2006 the Examiner issued an Office Action containing a statement that the arguments with respect to at least Claims 8 and 19 had been considered but were moot in view of the new ground(s) of rejection.[11] Also in the August 2006 Office Action, the Examiner set forth a rejection under §103(a) of Claims 8 and 19.[12]

This brings us to the first conflicting error. In the August 2006 Office Action, the Examiner recited, verbatim, the rejection contained in the January 2006 Office Action[13], even though the Examiner in the previously numbered paragraph therein stated that there were new grounds for rejection. Thus in the August 2006 Office Action the Examiner directed the Appellant to arguments contained in the January 2006 Office Action, after the Examiner stated that there were new grounds for rejection. Appellants filed a Response on November 28, 2006 presenting these inaccuracies to the Examiner and requesting that these inconsistencies be clarified.[14] The Examiner then issued an Office Action dated January 31, 2007.

This brings us to the second conflicting error. In the Response to Arguments section of the

[6] Appellants regret that the following detailed file history need be presented, but is necessary to clearly illustrate the continuing errors in the rejections pertaining to at least these claims.
[7] See Office Action dated January 19, 2006, at page 3, paragraph no. 3.
[8] See Response filed May 12, 2006, at pages 10-11.
[9] See Office Action dated June 29, 2006, at page 2, paragraph no. 3.
[10] See Office Action dated June 29, 2006, at page 5, paragraph no. 4.
[11] See Office Action dated August 28, 2006, at page 4, paragraph no. 3. Apparently, the Examiner found the arguments persuasive, hence the requirement of the new grounds of rejection.
[12] See Office Action dated August 28, 2006, at pages 5-6, paragraph no. 4.
[13] See the rejection contained in the Office Action dated August 28, 2006, at pages 5-6, paragraph no. 4 as compared with the rejection contained in the Office Action dated January 19, 2006, at pages 3-5, paragraph no. 3.

January 2007 Office Action, the Examiner, at least three times, refers the Appellant to the withdrawn June 2006 Office Action.[15] In and of itself, this may have been overlooked, but having to take into consideration that in the subsequent August 2006 Office Action the Examiner found the arguments persuasive and allegedly set forth new grounds for rejection[16], reliance on the June 2006 Office Action fails, not once, but twice.

This brings us to the third conflicting error. In the Claim Rejections section of the Office Action the Examiner stated that Claims 8 and 19 are rejected under §103(a), but this time directed Appellant to the August 28, 2006 Office Action.[17] As was previously stated, the August 2006 Office Action contained the rejection directing Appellant to the January 2006 Office Action, which during the interim between January 2006 and August 2006, an allegedly new ground for rejection was presented.

The Examiner has not set forth a rejection for Claims 8 and 19. In an attempt to resolve these errors, two telephone calls were placed to the Examiner's supervisor on March 8, 2007 and March 21, 2007. Voice mail messages were left. To date, no return call has been received by Appellants representatives. It was at that time, at least in part, that this Appeal became required.

1B. <u>Appellants' respectfully submit that the Examiner's allegation that Appellants have ignored evidence is unfounded</u>

The Examiner states, "The applicant ignores the evidence provided by the Examiner and fails to point out any errors in the rejection of the limitations in the claim."[18] It is unclear as to which rejections the Examiner referring. The new ground for rejection contained in the August 2006 Office Action referring back to an "old" ground for rejection contained in the January 2006 Office Action? The rejections contained in the withdrawn June 2006 Office Action? Appellants are not required to argue against rejections that have been withdrawn, rejections that have been superceded by "new grounds", or stale rejections.

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[14] See Response filed November 11, 2006, at page 11, 4th paragraph.
[15] See Office Action dated January 31, 2007, at page 2, paragraph no. 2.
[16] Appellants use "allegedly" to describe the new grounds for rejection since the grounds for rejection Claims 8 and 19 set forth in the August 2006 office action are a verbatim duplicate of the rejection contained in the January 2006 Office Action.
[17] See Office Action dated January 31, 2007, at page 7, paragraph no. 3.

The Examiner has not set forth a rejection for Claims 8 and 19.

1C. The Examiner mischaracterizes statements presented by Appellants

In the January 2006 Office Action, the Examiner stated:

> In addition, one of ordinary skill in the art at the time of the invention was made would have known that for a 64-bit data stream that there are only a **finite number of obvious puncturing patterns** to select from to achieve a particular rate required by a channel (Note: the puncturing patterns are obvious since there are only a **finite number of them**)."[19] [Emphasis added.]

In the May 2006 Response, Appellants set forth the following argument in response to the above statement by the Examiner. Appellants stated:

> Please note that with respect to Claims 9, 20, 25, 29-31, 33, 34, 36 and 38, the Examiner bases his obviousness rejections solely on an unsupportable conclusion that since there is only a finite number of puncturing patterns, masking sequences, and/or Walsh codes, any combination created therefrom would be obvious. Of course, Applicants respectfully disagree with the Examiner.
>
> Although there may be a finite number of patterns, sequences or codes, the 16 position/bit combinations of the 64 available positions/bits are astronomical, and therefore cannot be considered obvious. For example, with respect to determining a puncturing pattern, the total number of combinations to choose from is given by:
>
> $$_nC_k = \frac{n!}{k!(n-k)!}$$
>
> which produces a total number of possible combinations of ***488,526,937,079,580***. The amount of experimentation and analysis needed to determine optimal puncturing patterns in and of itself removes the claim element from any unsupported obviousness rejection.
>
> Still further, the claims of the present application incorporate the orthogonal sequences, the masking sequences and the puncturing patterns that further increase the possible combinations. The obviousness rejections of any of Claims 9, 20, 25, 29-31, 33, 34, 36 and 38 cannot stand.[20]

In the November 2006 Office Action the Examiner blatantly mischaracterizes the Appellants' statements by classifying the statements as an admission to the teachings of the cited references. The Examiner stated:

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[18] See Office Action dated January 31, 2007, at page 3, first paragraph, last sentence.
[19] See Office Action dated January 19, 2006, at page 5, last sentence, continuing onto page 6.
[20] See Response filed May 12, 2006, at page 10.

> Col. 1, line 36-40 and col. 9, lines 24-26 in Tong explicitly provide motivation citing that substantially uniform puncturing optimizes the punctured code and even the Applicant agrees that the teachings in Citation #4 and Wicker encompass all puncturing patterns including the substantially uniform puncturing patterns of Tong since in the second paragraph on page 10 of the Applicant's response filed 05/15/2006 suggests that Citation #4 and Wicker encompass all puncturing patterns associated with the formula in the second paragraph on page 10, which clearly indicates a reasonable expectation of success.[21]

Appellants' statements, as the Examiner well knows, were responsive to, and only to, the Examiner's unfounded and unsupported conclusion that since there is a finite number of puncturing patterns, therefore any specific puncturing pattern is obvious. Appellants' statements did not, in May 2006, and do not now, characterize the references.

Appellants adamantly protest the Examiner's mischaracterization of Appellants' statements to fit the holes in the Examiner's rejections.

1D. <u>The Examiner impermissibly redefines the claims of the present application</u>

In the August 2006 Office Action the Examiner opines, without citing any art for support:

> The Examiner asserts that all of the puncturing patterns in claim 9 are substantially uniformly distributed puncturing patterns with a minimum puncturing distance maximized to 3. The Examiner asserts that there are relatively few uniformly distributed puncturing patterns with a minimum puncturing distance maximized to 3 and furthermore the experimentation required to determine that maximized minimum puncturing distance sequences and optimal is Prior Art knowledge.[22]

In addition, the Examiner, under the improper heading of "Information Disclosure Statement", makes a formal requirement for information under 37 C.F.R. §1.105.[23] The Examiner has requested that a stipulation be made to each of his "assertions of facts". Included in the Examiner's "assertions of facts" were three requirements related to the above-cited statement.[24]

In the November 2006 Response, Appellants responded as follows:[25]

> 3. "The Examiner asserts that the puncturing patterns in claims 9, 20, 25, 29,

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[21] See Office Action dated November 28, 2006, at page 5, second full paragraph.
[22] See Office Action dated June 29, 2006, at page 3, last paragraph, continuing onto page 4.
[23] See Office Action dated August 28, 2006, at pages 2-3.
[24] See Office Action dated August 28, 2006, at page 2, last sentence, to page 3, fourth paragraph.
[25] See Response filed November 28, 2006, at pages 10-11.

36 and 38 are substantially uniform maximal minimum distance puncturing patterns."

3A. The information required to be submitted is unknown to or is not readily available to the party or parties from which it was requested.

4. "The Examiner requests that the Applicant either affirm or disagree with the statement - the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 are substantially uniform maximal minimum distance puncturing patterns."

4A. The information required to be submitted is unknown to or is not readily available to the party or parties from which it was requested. The term "substantially uniform maximal minimum distance puncturing patterns" is unknown to the Applicants.

5. "If the Applicant disagrees with the statement - the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 are substantially uniform maximal minimum distance puncturing patterns, the Examiner requests that the Applicant provide the designated common name for the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 and that the Applicant provide the common attributes that make the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 a species reciting support in the specification for such an allegation."

5A. The information required to be submitted is unknown to or is not readily available to the party or parties from which it was requested. The term "substantially uniform maximal minimum distance puncturing patterns" is unknown to the Applicants. There is no "designated common name" for the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 known to the Applicants. Applicants deny alleging that the puncturing patterns in claims 9, 20, 25, 29, 36 and 38 form a species.

Appellants continue to maintain that the term "substantially uniform maximal minimum distance puncturing patterns" is unknown to the Appellants. In addition, Appellants respectfully submit that the use by the Examiner of the term "substantially uniform maximal minimum distance puncturing patterns" is improper, until and unless proper support for its use is presented by the Examiner.

The Examiner was then directed to pages 18-19 of the specification, which clearly defines the puncturing positions/patterns as claimed in the claims of the present application.[26]

In spite of Appellants' request that the Examiner define the terms of the claims in accordance with the written description, the Examiner continues to base the arguments and rejections on these unsupported conclusions and definitions.[27]

It is respectfully requested that the Examiner be instructed to define terms in the claims in a manner that is consistent with the written description and supported by facts in evidence.

[26] See Response filed November 28, 2006, at page 11, third paragraph.
[27] See Office action dated January 31, 2007, at page 5, last paragraph, to page 6, first paragraph.

2. Independent Claims 8 and 19 are patentable over Citation #4 in view of Wicker

Independent Claims 8 and 19 were said to be unpatentable over Citation #4 in view of Wicker.[28]

Claim 8 recites an apparatus for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) into a sequence of 48 symbols in an NB-TDD mobile communication system, the apparatus for encoding having at least an orthogonal sequence generator, a mask sequence generator, and adder, and a puncturer. The apparatus includes an orthogonal sequence generator for creating a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI. The apparatus further includes a mask sequence generator for creating a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI. The apparatus also includes an adder for adding a biorthogonal sequence from the orthogonal sequence generator and a mask sequence from the mask sequence generator. The apparatus still further includes a puncturer for performing puncturing on sequences output from the adder so as to output the sequence of 48 symbols.

Claim 19 recites a method for encoding 10 consecutive input bits indicating a TFCI into a sequence of 48 symbols in an NB-TDD mobile communication system. The method includes creating in an orthogonal sequence generator a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI. The method further includes creating in a mask sequence generator a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI. The method also includes adding in an adder a biorthogonal sequence from the orthogonal sequence generator and a mask sequence from

[28] The Board is respectfully reminded that the rejection in paragraph no. 3 contained in the final Office Action dated January 31, 2007 directs the Appellant to the rejection contained in paragraph no. 4 of the August 2006 Office Action, which is a duplicate of the rejection contained in paragraph no. 3 of January 2006 Office Action, the arguments to which prompted the Examiner to state in paragraph no. 3 of the August 2006 Office Action that there are alleged "new grounds" of rejection. Therefore, the arguments presented herein are at least in part the arguments contained in the May 2006 Response that prompted the "new grounds" for rejection.

the mask sequence generator. The method still further includes performing puncturing in a puncturer on sequences output from the adder so as to output the sequence of 48 symbols.

Citation #4 discloses a text proposal regarding TFCI coding for Frequency Division Duplex (FDD); and Wicker discloses Reed-Muller codes.

2A. Since neither Citation #4 nor Wicker teach or disclose (48,10) coding, neither reference, nor any combination thereof, can be used to render obvious Claims 8 and 19

The Examiner has rejected Claims 8 and 19 under 35 U.S.C. §103(a) as being unpatentable over Citation #4 in view of Wicker. Citation #4 relates to (32,10) coding for improving (32,6) or (16,5) TFCI coding. Block coding is defined by a unique sequence, puncturing pattern, etc. in accordance with a coding length. When a coding length is changed, a different code is required by a channel; this requires changing the coding structure.

Claims 8 and 19 of the present application describe a new sequence and puncturing pattern for (48,10) coding. This is initially distinguished from Citation #4 that discloses (32,10) coding or Wicker that discloses general Reed-Muller codes and some examples thereof, e.g. Table 7-1. Furthermore, Wicker at Table 7-1, nor anywhere else for the matter, does not disclose any codes with a length of 48 as recited in Claims 8 and 19.

Block coding is defined by a unique sequence, puncturing pattern, etc. in accordance with a coding length. As stated above, when a coding length is changed, a completely different code has to be designed by a channel, thus changing the entire coding structure.

Since neither Citation #4 nor Wicker, nor any combination thereof, disclose the recitation of Claims 8 and 19 of the present application, of (48,10) coding, Claims 8 and 19 cannot be rendered obvious by Citation #4 in view of Wicker.

Based on at least the foregoing, reversal of the rejection of independent Claims 8 and 19 under §103(a) is respectfully requested.

2B. Independent Claims 8 and 19 are not rendered obvious by Citation #4 in view of Wicker

The Examiner has failed to show that each and every element of Claims 8 and 19, and in as complete detail as is contained therein, are taught in or suggested by the prior art. The Examiner has

failed to make out a prima facia case for an obviousness rejection, and thus Claims 8 and 19 are allowable.

3. Dependent Claims 41-44 are not unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7

Dependent Claim 41-44 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7. Without conceding the patentability per se of dependent Claims 41-44, these claims are likewise believed to be allowable by virtue of their dependence on Claims 8 or 19.

4. Dependent Claims 9 and 20 are patentable over Citation #4 and Wicker in view of Tong et al.

Dependent Claims 9 and 20 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al.

Each of Claims 9 and 20 recite wherein the puncturing is performed according to one of nine particular puncturing patterns. The nine puncturing patterns recited in Claims 9 and 20 are as follows:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}
{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}
{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}
{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}
{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}
{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}
{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}
{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}
{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}.

The Examiner stated that the specific puncturing patterns would be obvious to one skilled in the art.[29]

Initially, the Examiner based his obviousness rejections solely on an unsupportable conclusion that since there are only a finite number of puncturing patterns, masking sequences,

[29] See Office Action dated August 28, 2006, at pages 6-8, paragraph no. 5.

and/or Walsh codes, any combination created therefrom would be obvious. Although there may be a finite number of patterns, sequences or codes, the 16 position/bit combinations of the 64 available positions/bits are astronomical, and therefore cannot be considered obvious. For example, with respect to determining a puncturing pattern, the total number of combinations to choose from is given by:

$$ {}_nC_k = \frac{n!}{k!(n-k)!} $$

which produces a total number of possible combinations of ***488,526,937,079,580***. The amount of experimentation and analysis needed to determine optimal puncturing patterns in and of itself removes the claim element from any unsupported obviousness rejection.[30]

The Examiner then cited Tong et al. for the basis of his conclusions that the nine specific puncturing patterns are obvious. Tong et al. discloses rate matching and channel interleaving for a communications system. It is not disputed that Tong et al. teaches that it is desirable to distribute the omitted or repeated bits as evenly as possible, with as great a distance as possible between punctured or repeated bits in the de-interleaved frames.[31] Tong et al. goes on to state that determining this distribution should be done in a manner that is easy to implement and that is relatively independent of variables such as the frame-size, number of frames, and puncturing rate.[32] These additional factors serve to continue to illustrate the complexity in determining the ideal puncturing positions.

Furthermore, Tong et al. itself illustrates the difficulty and skill required to determine an optimal puncturing pattern. Tong et al. sets forth an example at col. 8, line 23 - col. 9, line 29. In this example, Tong et al. uses its teachings to describe a punctured matrix. The puncturing pattern is set forth. Tong et al. describes this puncturing pattern as follows:[33]

> The channel interleaved and rate matched data bits are derived column by column from Table 3, i.e., with the order [57, 35, . . . , 51, 7, 67, 40, . . . , 26, 4]. The punctured bits are 2, 9, 11, 16, 25, 29, 31, 32, 34, 38, 47, 54, 61, 64, 68, and 75, for which the maximum puncture distance is 9 (25-16) and the minimum puncture distance is 1 (32-31); this small minimum puncture distance indicates that this particular example is not optimum, a larger minimum puncture distance being

[30] See Response filed May 12, 2006, at page 10.
[31] See Tong et al., at col. 1, lines 36-39.
[32] See Tong et al., at col. 1, lines 39-42.
[33] See Tong et al., at col. 9, lines 18-29.

> desirable. It can be appreciated that numerous other determinations of the parameters, and in particular of the parameter e_{os}, can be provided to optimize the puncturing process.

The puncturing pattern of Tong et al. "is not optimized", thus illustrating the difficulty in determining an optimized puncturing pattern. "It can be appreciated that ***numerous*** other determinations of the parameters, and in particular of the parameter e_{os}, can be provided to optimize the puncturing process." [Emphasis added.]

Tong et al. also teaches, "More particularly, the design of an appropriate, and desirably optimized, rate matching pattern of punctured or repeated bits within the matrix of bits after the channel interleaving process represents a very complex or impractical task."[34]

Appellants' teach that the minimum distance of the (48,10) encoder varies depending on the positions of the 16 punctured symbols. Combinations of the 16 punctured positions, providing superior performance, are shown below. When using the following combinations of the punctured positions, the (48,10) encoder has the minimum distance of 18 and provides superior weight distribution.[35]

As is well known in the art, the minimum distance of an encoder varies depending on the positions of the punctured symbols. The specific puncturing pattern recited in the claims provides superior performance and provide superior weight distribution. Extensive research and analysis are required to determine the exact pattern that provides the best performance. The claims of the present application relate to (48,10) coding, while Citations #4 and #7 relate to a (32,10) coding method to improve a (32,6) or (16,5) TFCI coding introduced in the 3rd Generation partnership Project (3GPP) Standards Conference. In Reed Muller coding, a unique sequence and puncturing pattern must be defined according to a coding length. Coding performance is heavily influenced by the definition of the patterns. For this reason, the 3GPP Standards Conference conducted extensive discussions based on numerous articles submitted in order to adopt a coding method having optimal performance. Therefore, the present invention, and Citations #4 and #7 are evidence in and of themselves of the extensive research required to realize these coding techniques.

Appellants' position remains that determining these positions takes great skill and innovation.

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[34] See Tong et al., at col. 5, line 65 – col. 6, line 2.

The particular puncturing patterns at the time of the invention were not known in the art. It was not until Appellants, through the use of skill and innovation, that the particular puncturing patterns were determined.

Since neither Citation #4 nor Wicker nor Tong et al., nor any combination thereof, disclose the particular puncturing patterns of Claims 9 and 20 of the present application, Claims 9 and 20 cannot be rendered obvious by Citation #4 and Wicker in view of Tong et al.

Based on at least the foregoing, reversal of the rejection of dependent Claims 9 and 20 under §103(a) is respectfully requested.

4A. Dependent Claims 9 and 20 are not rendered obvious by Citation #4 and Wicker in view of Tong et al.

The Examiner has failed to show that each and every element of Claims 9 and 20, and in as complete detail as is contained therein, are taught in or suggested by the prior art. The Examiner has failed to make out a prima facia case for an obviousness rejection, and thus Claims 9 and 20 are allowable.

5. Dependent Claims 36 and 38 are not unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7

Dependent Claim 36 and 38 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7. Each of Claims 36 and 38 recite the puncturing patterns also recited in Claims 9 and 20.

Since these features are similar to features recited in Claims 9 and 20, and Citation #7 does not cure the defects of Citation #4, Wicker and Tong et al., the arguments set forth above in section 4 with respect to Claims 9 and 20 are also applicable to Claims 36 and 38.

Since neither Citation #4 nor Wicker nor Tong et al. nor Citation #7, nor any combination thereof, disclose the particular puncturing patterns of Claims 36 and 38 of the present application, Claims 36 and 38 cannot be rendered obvious by Citation #4 and Wicker in view of Tong et al. and Citation #7.

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[35] See Specification, at pages 18-19.

Based on at least the foregoing, reversal of the rejection of dependent Claims 36 and 38 under §103(a) is respectfully requested.

6. Independent Claims 25 and 29 are patentable over Citation #4 and Wicker in view of Tong et al. and Citation #7

Independent Claims 25 and 29 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7.[36]

Claim 25 recites an apparatus for encoding 10 consecutive input bits indicating a TFCI of each 48 symbols in a mobile communication system, the apparatus for encoding having at least a second order Reed Muller code generator and a puncturer. The apparatus includes a (64,10) second order Reed Muller code generator for generating 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits. The apparatus further includes a puncturer for puncturing 16 symbols out of the 64 coded symbols; the puncturing positions of the 16 symbols are {0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}.

Claim 29 recites a method for encoding 10 consecutive input bits indicating a TFCI of each 48 symbols in an NB-TDD mobile communication system. The method includes second order Reed Muller coding for generating in a second order Reed Muller code generator 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits. The method further includes generating 48 symbols by puncturing 16 symbols out of the 64 coded symbols; the puncturing positions of the 16 symbols in the puncturer are {0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}.

Citation #4 discloses a text proposal regarding Transport Format Combination Indicator (TFCI) coding for Frequency Division Duplex (FDD); Wicker discloses Reed-Muller codes; Tong et al. discloses rate matching and channel interleaving for a communications system; and Citation #7 discloses harmonization impact on TFCI and new optimal coding for extended TFCI with almost no complexity increase.

6A. Since neither Citation #4 nor Wicker nor Tong et al. nor Citation #7 teach or disclose (48,10)

[36] See Office Action dated August 28, 2006, at pages 8-11, paragraph no. 6.

coding, neither reference, nor any combination thereof, can be used to render obvious Claims 25 and 29

The Examiner has rejected Claims 25 and 29 under 35 U.S.C. §103(a) as being unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7. Citation #4 and Citation #7 relate to (32,10) coding for improving (32,6) or (16,5) TFCI coding. Block coding is defined by a unique sequence, puncturing pattern, etc. in accordance with a coding length. When a coding length is changed, a different code is required by a channel; this requires changing the coding structure.

Claims 25 and 29 of the present application describe a new sequence and puncturing pattern for (48,10) coding. This is initially distinguished from Citation #4 and Citation #7 that discloses (32,10) coding or Wicker that discloses general Reed-Muller codes and some examples thereof, e.g. Table 7-1.

Block coding is defined by a unique sequence, puncturing pattern, etc. in accordance with a coding length. As stated above, when a coding length is changed, a different code has to be designed by a channel, thus changing the coding structure.

Since neither Citation #4, Wicker, Tong et al. nor Citation #7, nor any combination thereof, disclose the recitation of Claims 25 and 29 of the present application, of (48,10) coding, Claims 25 and 29 cannot be rendered obvious by Citation #4 and Wicker in view of Tong et al. and Citation #7.

Based on at least the foregoing, reversal of the rejection of independent Claims 25 and 29 under §103(a) is respectfully requested.

6B. Since neither Citation #4 nor Wicker nor Tong et al. nor Citation #7 teach or disclose puncturing positions of the 16 symbols in a puncturer are {0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}, neither reference, nor any combination thereof, can be used to render obvious Claims 25 and 29

Independent Claim 25 and 29 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7. Each of Claims 25 and 29 recite at least one of the puncturing patterns also recited in Claims 9 and 20.

Since these features are similar to features recited in Claims 9 and 20, and Citation #7 does not cure the defects of Citation #4, Wicker and Tong et al., the arguments set forth above in section 4 with respect to Claims 9 and 20 are also applicable to Claims 25 and 29.

Since neither Citation #4 nor Wicker nor Tong et al. nor Citation #7, nor any combination thereof, disclose the particular puncturing patterns of Claims 25 and 29 of the present application, Claims 25 and 29 cannot be rendered obvious by Citation #4 and Wicker in view of Tong et al. and Citation #7.

Based on at least the foregoing, reversal of the rejection of dependent Claims 25 and 29 under §103(a) is respectfully requested.

6C. Independent Claims 25 and 29 are not rendered obvious by Citation #4 and Wicker in view of Tong et al. and Citation #7

The Examiner has failed to show that each and every element of Claims 25 and 29, and in as complete detail as is contained therein, are taught in or suggested by the prior art. The Examiner has failed to make out a prima facia case for an obviousness rejection, and thus Claims 25 and 29 are allowable.

7. Dependent Claims 30, 31, 33, 34, 36 and 38-40 are not unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7

Dependent Claim 30, 31, 33, 34, 36 and 38-40 were said to be unpatentable over Citation #4 and Wicker in view of Tong et al. and Citation #7. Without conceding the patentability per se of dependent Claims 30, 31, 33, 34, 36 and 38-40, these claims are likewise believed to be allowable by virtue of their dependence on either Claims 25 or 29.

CONCLUSION

As the Examiner has failed to make out a prima facie case for an obviousness rejection, the rejection of Claims 8, 9, 19, 20, 25, 29-31, 33, 34, 36 and 38-44 must be reversed.

It is well settled that in order for a rejection under 35 U.S.C. §103(a) to be appropriate, the claimed invention must be shown to be obvious in view of the prior art as a whole. A claim may be found to be obvious if it is first shown that all of the recitations of a claim are taught in the prior art or are suggested by the prior art. In re Royka, 490 F.2d 981, 985, 180 U.S.P.Q. 580, 583 (C.C.P.A.

1974), cited in M.P.E.P. §2143.03.

The Examiner has failed to show that all of the recitations of Claims 8, 9, 19, 20, 25, 29-31, 33, 34, 36 and 38-44 are taught or suggested by the either Citation #4 or Wicker, or the combination thereof. Accordingly, the Examiner has failed to make out a prima facie case for an obviousness rejection.

Independent Claims 8 and 19 are not rendered unpatentable by either Citation #4 or Wicker, or the combination thereof. Therefore, the rejections of Claims 8 and 19 must be reversed.

Dependent Claims 9 and 20 are not rendered unpatentable by Citation #4, Wicker, or Tong et al., or the combination thereof. Therefore, the rejections of Claims 9 and 20 must be reversed.

Independent Claims 25 and 29 are not rendered unpatentable by Citation #4, Wicker, Tong et al. or Citation #7, or the combination thereof. Therefore, the rejections of Claims 25 and 29 must be reversed.

Dated: June 8, 2007

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CLAIMS APPENDIX

1-7. (Cancelled)

8. (Previously Presented) An apparatus for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) into a sequence of 48 symbols in an NB-TDD mobile communication system, the apparatus for encoding having at least an orthogonal sequence generator, a mask sequence generator, and adder, and a puncturer, the apparatus comprising:

an orthogonal sequence generator for creating a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI;

a mask sequence generator for creating a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI;

an adder for adding a biorthogonal sequence from the orthogonal sequence generator and a mask sequence from the mask sequence generator; and

a puncturer for performing puncturing on sequences output from the adder so as to output the sequence of 48 symbols.

9. (Original) The apparatus as claimed in claim 8, wherein the puncturer performs puncturing according to one of following puncturing patterns:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

10-18. (Cancelled)

19. (Previously Presented) A method for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each of successively transmitted frames into a sequence of 48 symbols in an NB-TDD mobile communication system, comprising:

creating in an orthogonal sequence generator a plurality of biorthogonal sequences having a length of at least 2^n where $2^n>48$, and outputting a biorthogonal sequence selected from the biorthogonal sequences by first information bits of the TFCI;

creating in a mask sequence generator a plurality of mask sequences, and outputting a mask sequence selected from the mask sequences by second information bits of the TFCI;

adding in an adder the selected biorthogonal sequence and the mask sequence; and

performing puncturing in a puncturer on sequences output from the adder so as to output the sequence of 48 symbols.

20. (Original) The method as claimed in claim 19, wherein the puncturing is performed according to one of following puncturing patterns:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

21-24. (Cancelled)

25. (Previously Presented) An apparatus for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each 48 symbols in a mobile communication system, the apparatus for encoding having at least a second order Reed Muller code generator and a puncturer, the apparatus comprising:

a (64,10) second order Reed Muller code generator for generating 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits; and

a puncturer for puncturing 16 symbols out of the 64 coded symbols wherein puncturing positions of the 16 symbols are as follows:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}.

26-28. (Cancelled)

29. (Previously Presented) A method for encoding 10 consecutive input bits indicating a TFCI (Transport Format Combination Indicator) of each 48 symbols in an NB-TDD mobile communication system, comprising the step of:

second order Reed Muller coding for generating in a second order Reed Muller code generator 64 coded symbols by using length 64 Walsh codes and length 64 masks in response to the input bits; and

generating 48 symbols by puncturing 16 symbols out of the 64 coded symbols wherein puncturing positions of the 16 symbols in a puncturer are as follows:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}.

30. (Previously Presented) The method as claimed in claim 29, wherein the Walsh codes comprise a 1st Walsh code, a 2nd Walsh code, a 4th Walsh code, an 8th Walsh code, a 16th Walsh code and a 32nd Walsh code, selected from 64 Walsh orthogonal sequences of length 64.

31. (Previously Presented) The method as claimed in claim 29, wherein the masks comprise mask sequences of

0011010101101111101000110000011011110110010100111001111111000101,
0100011111010001110110101110110111101100010010110100011011l1000, and
0001100011100111110101001101010010111101101111010111000110001110.

32. (Previously Presented) The apparatus as claimed in claim 25, wherein the encoder comprises:

a 1-bit generator for generating a sequence of same symbols;

a basis orthogonal sequence generator for generating a plurality of basis orthogonal sequences;

a basis mask sequence generator for generating a plurality of basis mask sequences; and

an operator for receiving the TFCI including a first information part indicating conversion to a biorthogonal sequence, a second information part indicating conversion to an orthogonal sequence and a third information part indicating conversion to a mask sequence, and generating the sequence of 64 symbols by combining an orthogonal sequence selected from the basis orthogonal sequences by the second information part, a biorthogonal sequence constructed by a combination of the selected orthogonal sequence and the same symbols selected by the first information part, and a mask sequence selected by the third information part.

33. (Previously Presented) The apparatus as claimed in claim 25, wherein the length 64 Walsh codes comprise a 1st Walsh code, a 2nd Walsh code, a 4th Walsh code, an 8th Walsh code, a 16th Walsh code and a 32nd Walsh code, selected from 64 orthogonal sequences of length 64.

34. (Previously Presented) The apparatus as claimed in claim 25, wherein the masks comprise mask sequences of
0011010101101111101000110000011011110110010100111001111111000101,
0100011111010001110110101110110111101100010010110100011011l1000, and
0001100011100111110101001101010010111101101111010111000110001110.

35. (Previously Presented) The apparatus as claimed in claim 32, wherein the operator comprises:

a first multiplier for multiplying the same symbols by the first information part;

a plurality of second multipliers for multiplying the basis orthogonal sequences by TFCI bits constituting the second information part;

a plurality of third multipliers for multiplying the basis mask sequences by TFCI bits constituting the third information part; and

an adder for generating the sequence of 64 symbols by adding outputs of the first to third multipliers.

36. (Previously Presented) The apparatus as claimed in claim 25, wherein the puncturer performs puncturing according to any one of puncturing patterns given below:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

37. (Previously Presented) The method as claimed in claim 29, wherein the encoding step comprises the steps of:

generating a sequence of same symbols;

generating a plurality of basis orthogonal sequences;

generating a plurality of basis mask sequences; and

receiving the TFCI including a first information part indicating conversion to a biorthogonal sequence, a second information part indicating conversion to an orthogonal sequence and a third

information part indicating conversion to a mask sequence, and generating the sequence of 64 symbols by combining an orthogonal sequence selected from the basis orthogonal sequences by the second information part, a biorthogonal sequence constructed by a combination of the selected orthogonal sequence and the same symbols selected by the first information part, and a mask sequence selected by the third information part.

38. (Previously Presented) The method as claimed in claim 29, wherein the puncturing is performed according to any one of puncturing patterns given below:

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

{0, 4, 8,13,16,21,25,28,32,37,43,44,49,52,56,62}

{0, 4, 8,13,16,21,25,31,32,37,43,44,49,52,56,61}

{0, 4, 8,13,18,21,25,30,35,36,40,46,50,53,57,62}

{0, 4, 8,13,18,21,25,30,35,37,40,47,50,53,57,62}

{0, 4, 8,13,19,22,27,30,33,36,41,44,49,55,58,61}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,56,63}

{0, 4, 8,13,19,22,27,30,33,36,41,44,50,52,58,61}

{0, 4, 8,13,16,20,27,31,34,38,41,44,50,54,57,61}

39. (Previously Presented) The apparatus as claimed in claim 25, wherein the (64,10) second order Reed Muller code generator generates 64 coded symbols by using length 64 all 1's sequence in response to the input bits.

40. (Previously Presented) The method as claimed in claim 29, wherein the (64,10) second order Reed Muller coding step uses length 64 all 1's sequence in response to the input bits to generate 64 coded symbols.

41. (Previously Presented) The apparatus as claimed in claim 8, wherein the plurality of biorthogonal sequences is comprised of a all 1's sequence, a 1st Walsh code, a 2nd Walsh code, a 4th

Walsh code, an 8^{th} Walsh code, a 16^{th} Walsh code and a 32^{nd} Walsh code, selected from 64 Walsh orthogonal sequences of length 64.

42. (Previously Presented) The apparatus as claimed in claim 8, wherein the plurality of mask sequences is comprised of
0011010101101111101000110000011011110110010100111001111111000101,
0100011111010001111011010111101101111011000100101101000110111000 and
0001100011100111110101001101010010111101101111010111000110001110.

43. (Previously Presented) The method as claimed in claim 19, wherein the plurality of biorthogonal sequences is comprised of a all 1's sequence, a 1^{st} Walsh code, a 2^{nd} Walsh code, a 4^{th} Walsh code, an 8^{th} Walsh code, a 16^{th} Walsh code and a 32^{nd} Walsh code, selected from 64 Walsh orthogonal sequences of length 64.

44. (Previously Presented) The method as claimed in claim 19, wherein the plurality of mask sequences is comprised of
0011010101101111101000110000011011110110010100111001111111000101,
0100011111010001111011010111101101111011000100101101000110111000 and
0001100011100111110101001101010010111101101111010111000110001110.

EVIDENCE APPENDIX

There is no evidence submitted pursuant to 37 C.F.R. 1.130, 1.131 or 1.132.

The following evidence submitted by the Examiner and relied upon by the Appellants is supplied hereto:

1. Text Proposal Regarding TFCI Coding For FDD, TSGR1#7(99)D69, August 30 - September 3, 1999 (Citation #4);

2. Stephen B. Wicker, Error Control Systems for Digital Communication and Storage, Prentice-Hall, 1996, pages 149-155 (Wicker);

3. U.S. Patent 6,744,744 (Tong et al.); and

4. Harmonization Impact On TFCI And New Optimal Coding For Extended TFCI With Almost No Complexity Increase, TSGR#6(99)970, July 13-16, 1999 (Citation #7).

4

TSG-RAN Working Group1 meeting #7
Hanover, Germany,
August 30 – September 3, 1999

TSGR1#7(99)D69

Agenda Item: Ad Hoc 4 Report and Text Proposal

Source: Samsung Electronics Co. Ltd.

Title: **Text proposal regarding TFCI coding for FDD (rev. of R1-99b61)**

Document for: Approval

Abstract

In Ad Hoc 4 meeting, Samsung's new TFCI coding scheme was approved as working assumption. During the meeting several comments were raised and we revised the text proposal based on the comments. This document is the revised text proposal of Tdoc R1-99b61 regarding TFCI coding for FDD mode.

---------------------- Start of Text Proposal ----------------------

4.3 Coding for layer 1 control

4.3.1 Coding of Transport-format-combination indicator (TFCI)

The number of TFCI bits is variable and is set at the beginning of the call via higher layer signalling. ~~Encoding of the TFCI bits depends on the number of them. If there are at most 6 bits of TFCI, the channel encoding is done as described in section 4.3.1.1. Correspondingly, if the TFCI word is extended to 7-10 bits the channel encoding is done as explained in the section 4.3.1.2.~~ For improved TFCI detection reliability, in downlink, repetition is used by increasing the number of TFCI bits within a slot.

~~4.3.1.1 Coding of default TFCI word~~

~~If the number of TFCI bits is up to 6, the~~ The TFCI bits are encoded using (30, 10) punctured ~~biorthogonal (30, 6) block code~~ sub-code of the second order Reed-Muller code. The coding procedure is as shown in Figure 1.

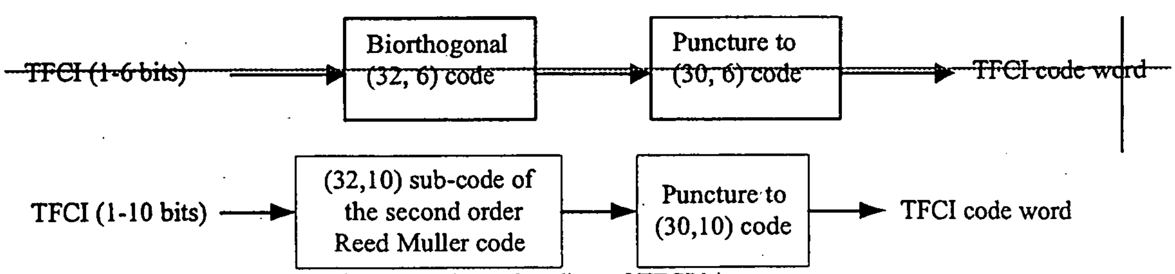


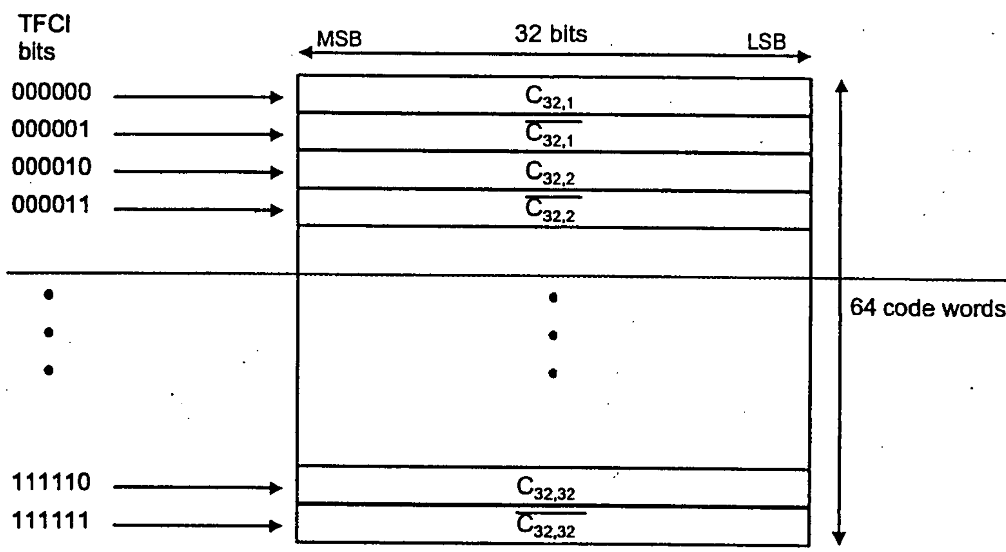
Figure 1: Channel coding of TFCI bits

If the TFCI consist of less than 10~~6~~ bits, it is padded with zeros to 10~~6~~ bits, by setting the most significant bits to zero. The receiver can use the information that not all 10~~6~~ bits are used for the TFCI, thereby

reducing the error rate in the TFCI decoder. The length of the TFCI code word is 30 bits. Thus there are 2 bits of (encoded) TFCI in every slot of the radio frame.

~~The TFCI bits are first encoded using biorthogonal (32, 6) code. The code words of the biorthogonal block code are from the level 32 of the code three of OVSF codes defined in document TS 25.213. The code words, $C_{32,I}$, $I = 1,\ldots,32$, form an orthogonal set, $S_{C_{32}} = \{C_{32,1}, C_{32,2},\ldots,C_{32,32}\}$, of 32 code words of length 32 bits. By taking the binary complements of the code words of $S_{C_{32}}$, another set, $\overline{S}_{C_{32}} = \{\overline{C}_{32,1}, \overline{C}_{32,2},\ldots,\overline{C}_{32,32}\}$ is formed. These two sets are mutually biorthogonal yielding total of 64 different code words.~~

~~Mapping of the TFCI bits to the biorthogonal code words is done as shown in the Figure 9.~~



~~Figure 2: Mapping of TFCI bits to biorthogonal code words~~

~~Biorthogonal code words, $C_{32,I}$ and $\overline{C}_{32,I}$, are encoded into TFCI code words of length 30 bits by puncturing the two least significant bits (i.e. the two last bits on right in Figure 9).~~

~~4.3.1.2Coding of extended TFCI word~~

~~If the number of TFCI bits is 7-10 the TFCI information field is split into two words of length 5 bits as shown in the following formula: .~~

~~$n := \lfloor \sqrt{TFCI} \rfloor$; n is the largest integer being smaller than or equal to the square root of the transmitted TFCI value.~~

~~if $TFCI < n^2 + n$~~

~~then $Word1 := n$; $Word2 := TFCI - n^2$~~

~~else $Word2 := n$; $Word1 := n^2 + 2n - TFCI$~~

~~Both of the words are first encoded using biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_{16}} = \{C_{16,1}, C_{16,2},\ldots,C_{16,16}\}$ and its~~

~~binary complement, $\bar{S}_{C_{16}} = \{\bar{C}_{16,1}, \bar{C}_{16,2}, \ldots, \bar{C}_{16,16}\}$. Words of set $S_{C_{16}}$ are from the level 16 of the code three of OVSF codes defined in document TS 25.213. The mapping of information bits to code words is shown in the Table 5.~~

~~Table 1: Mapping of information bits to code words for biorthogonal (16, 5) code~~

~~Information bits~~	~~Code word~~
~~00000~~	~~$C_{16,1}$~~
~~00001~~	~~$\bar{C}_{16,1}$~~
~~00010~~	~~$C_{16,2}$~~
~~...~~	~~...~~
~~11101~~	~~$\bar{C}_{16,15}$~~
~~11110~~	~~$C_{16,16}$~~
~~11111~~	~~$\bar{C}_{16,16}$~~

~~Biorthogonal code words, $C_{16,i}$ and $\bar{C}_{16,i}$, are then encoded into TFCI code words of length 15 bits by puncturing the least significant bit (i.e. the rightmost bit).~~
Firstly, TFCI is encoded by the (32,10) sub-code of second order Reed-Muller code. The code words of the (32,10) sub-code of second order Reed-Muller code are linear combination of 10 basis sequences: all 1's, 5 OVSF codes ($C_{32,2}$, $C_{32,3}$, $C_{32,5}$, $C_{32,9}$, $C_{32,17}$), and 4 masks (Mask1, Mask2, Mask3, Mask4). The 4 mask sequences are as following Table 1.

Mask 1	00101000011000111111000001110111
Mask 2	00000001110011010110110111000111
Mask 3	00001010111110010001101100101011
Mask 4	00011100001101110010111101010001

Table 1. Mask sequences

For information bits a_0, a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9 (a_0 is LSB and a_9 is MSB), the encoder structure is as following Figure 2.

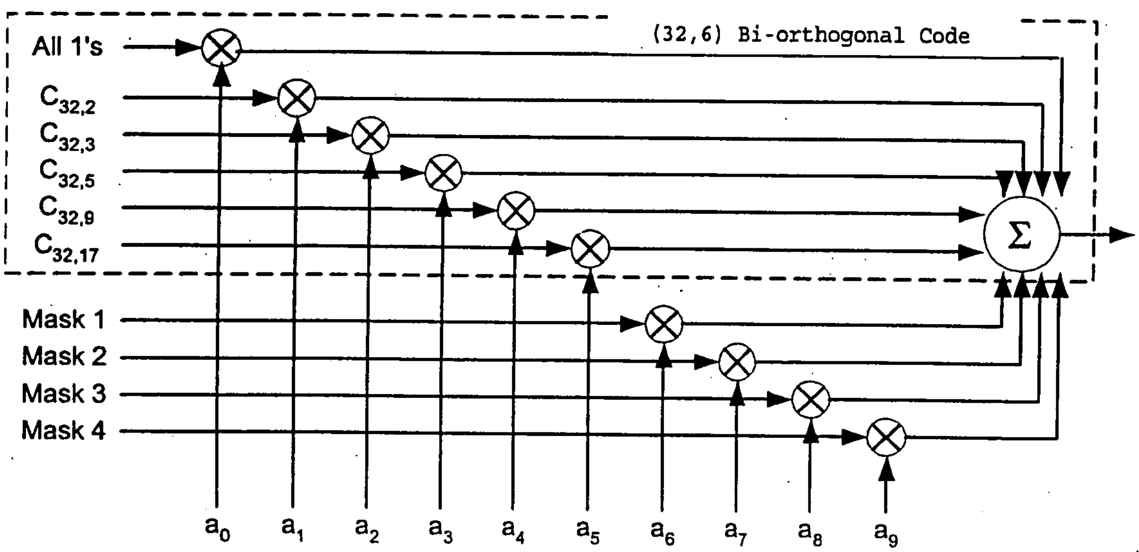


Figure 2. Encoder structure for (32,10) sub-code of second order Reed-Muller code

Then, the code words of the (32,10) sub-code of second order Reed-Muller code are punctured into length

30 by puncturing 1-st and 17-th bits.

4.3.2 Operation of Transport-format-combination indicator (TFCI) in ~~soft handover~~Split Mode

In the case of DCH in ~~soft handover situation~~Split Mode, ~~each Node B shall transmit the identical (30,6) code word for the UE.~~

~~In the case of extended TFCI coding,~~ the Node B shall operate with ~~one of the~~ as follows~~following modes~~:

~~- Both words are identical from all links~~

- If one of the links is associated with a DSCH, the TFCI code word may be split in such a way that the code word relevant for TFCI activity indication is not transmitted from every Node B. The use of such a functionality shall be indicated by higher layer signalling.

TFCI information is encoded by biorthogonal (16, 5) block code. The code words of the biorthogonal (16, 5) code are from two mutually biorthogonal sets, $S_{C_{16}} = \{C_{16,1}, C_{16,2}, ..., C_{16,16}\}$ and its binary complement, $\overline{S}_{C_{16}} = \{\overline{C}_{16,1}, \overline{C}_{16,2}, ..., \overline{C}_{16,16}\}$. Code words of set $S_{C_{16}}$ are from the level 16 of the code three of OVSF codes defined in document TS 25.213. The mapping of information bits to code words is shown in the Table 2.

Table 2: Mapping of information bits to code words for biorthogonal (16, 5) code

Information bits	Code word
00000	$C_{16,1}$
00001	$\overline{C}_{16,1}$
00010	$C_{16,2}$
...	...
11101	$\overline{C}_{16,15}$
11110	$C_{16,16}$
11111	$\overline{C}_{16,16}$

Biorthogonal code words, $C_{16,l}$ and $\overline{C}_{16,l}$, are then punctured into length 15 by puncturing the 1-st bit.

4.3.3 ~~Interleaving~~ Mapping of TFCI words

4.3.3.1 ~~Interleaving~~ Mapping of ~~default~~ TFCI word

As only one code word for TFCI ~~of maximum length of 6 bits~~ is needed no channel interleaving for the encoded bits are done. Instead, the bits of the code word are directly mapped to the slots of the radio frame as depicted in the Figure 3. Within a slot the more significant bit is transmitted before the less significant bit.

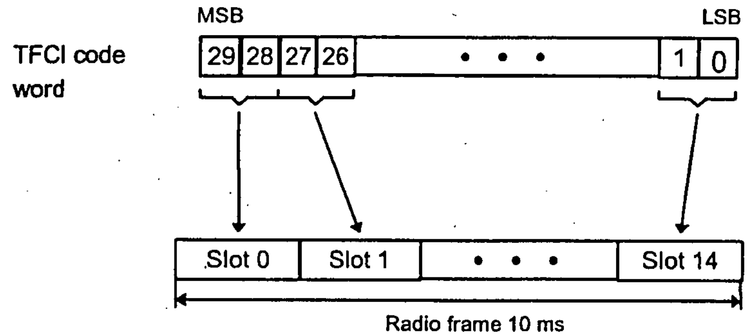


Figure 3: ~~Time multiplexing~~Mapping of TFCI code words ~~of (30, 6) code~~ to the slots of the radio frame

4.3.3.2 ~~Interleaving~~ Mapping of ~~extended~~ TFCI word in Split Mode

After channel encoding of the two 5 bit TFCI words there are two code words of length 15 bits. They are ~~interleaved and~~ mapped to DPCCH as shown in the Figure 4. Note that $b_{1,i}$ and $b_{2,i}$ denote the bit i of code word 1 and code word 2, respectively.

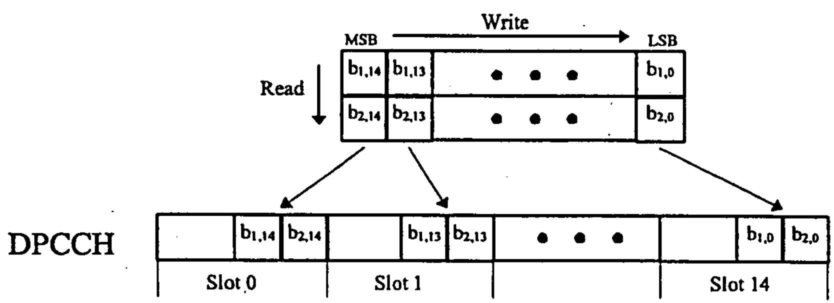


Figure 4: ~~Interleaving~~ Mapping of ~~extended~~ TFCI code words to the slots of the radio frame in Split Mode

============ End of Text Proposal ============

References

[1] 3GPP TSGR1#6 (99)xxx, 'Harmonization impact on TFCI and New Optimal Coding for extended TFCI with almost no Complexity increase(Rev2)', Source: Samsung

[2] 3GPP TSGR1#7 (99)a86, 'TS 25.212 V2.0.1 (1999-08) Multiplexing and channel coding (FDD)'

[3] 3GPP TSGR1#7 (99)a61, 'Text proposal regarding TFCI coding for FDD', Samsung

Error Control Systems for Digital Comunication and Storage

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11. Find the generator polynomial for a ternary quadratic residue code of length 11.
12. Find the generator polynomial for a ternary quadratic residue code of length 13.

Golay codes

13. Prove that a code is self-dual only if its length n is twice its dimension k.
14. Prove that all of the code words in $\mathscr{G}_{23}$ have weights greater than 4.
15. Prove that all of the code words in $\mathscr{G}_{11}$ have weights greater than 3.
16. Use the arithmetic decoding algorithm to decode the following received words.
    (a) $\mathbf{r} = (1000\ 1000\ 0000\ 1001\ 0001\ 1101)$
    (b) $\mathbf{r} = (1011\ 1000\ 0000\ 1110\ 0000\ 1100)$
    (c) $\mathbf{r} = (1000\ 1110\ 0011\ 0100\ 0110\ 1000)$
    (d) $\mathbf{r} = (1111\ 0111\ 1110\ 0011\ 1010\ 0111)$
17. Use the algebraic decoding algorithm to decode the following received words.
    (a) $\mathbf{r} = (1100\ 0000\ 0000\ 1100\ 0000\ 0000)$
    (b) $\mathbf{r} = (0000\ 0001\ 1111\ 0000\ 0000\ 0000)$
    (c) $\mathbf{r} = (1010\ 1010\ 0000\ 1000\ 1100\ 0100)$
    (d) $\mathbf{r} = (1101\ 1111\ 0001\ 1111\ 0100\ 1111)$

7

Reed-Muller Codes

The codes that are now called Reed-Muller (RM) codes were first described by Muller in 1954 using a "Boolean net function" language. That same year Reed [Ree1] recognized that Muller's codes could be represented as multinomials over the binary field. The resulting "Reed-Muller" (RM) codes were an important step beyond the Hamming and Golay codes of 1949 and 1950 because of their flexibility in correcting varying numbers of errors per code word. Since their discovery, RM codes have been used in a number of interesting applications. For example, a first-order RM code of length 32 provided error control on all of the United States' *Mariner*-class deep space probes flown between 1969 and 1977. RM codes have also enjoyed a great deal of attention from the more theoretically inclined researchers. RM codes have an enormous wealth of algebraic and combinatorial structure that has kept mathematicians busy for almost forty years. Part of this theoretical work has led to the discovery of other interesting codes, including the Kerdock and Preparata codes.

For the past twenty years RM codes have not received the frequent application they enjoyed between 1954 and 1968. They lost their hold on the space program when convolutional codes and sequential decoders were adopted for the *Pioneer* missions [Mas2]. It had also been recognized that RM codes do not perform as well as long BCH and Reed-Solomon codes. When an efficient decoding algorithm was discovered for the latter in 1968 [Ber1], RM codes were no longer as attractive to design engineers. It would be a great mistake, however, to believe that BCH and Reed-Solomon codes are a superior choice relative to RM codes for all applications. The short low-rate RM codes and the first-order RM codes have roughly the same minimum distances as binary BCH codes of the same length. RM codes also enjoy

a tremendous benefit in that they have an extremely fast maximum likelihood decoding algorithm (the Reed decoding algorithm [Reel]). No such algorithm has been discovered for BCH and Reed-Solomon codes. As data rates on optical channels push electronic encoders and decoders to the limits of device technology, Reed-Muller codes may once again see extensive application.

The next section describes the basic structure of RM codes. This is followed by a discussion of the Reed decoding algorithm, which, among other things, leads to some nice four-dimensional art work. In the last section we examine the first-order RM codes in depth. A high-speed soft-decision decoding algorithm related to the fast-Fourier-transform is presented.

7.1 THE CONSTRUCTION OF REED-MULLER CODES

Reed-Muller codes are most easily described through the use of Boolean functions. A Boolean function in m variables $f(x_1, x_2, \ldots, x_m)$ is defined as a mapping from the vector space V_m of binary m-tuples $\{(x_1, \ldots, x_m)\}$ into the set of binary numbers $\{0, 1\}$. Boolean functions are completely described by a truth table containing $(m + 1)$ rows. The first m rows form an $(m \times 2^m)$ matrix that contains as columns all 2^m binary m-tuples. The bottom row contains the binary value assigned to each of the m-tuples by the Boolean function. There exist a number of techniques for using this truth table to develop an algebraic expression for the function in terms of the m variables in its argument. Some readers may have become familiar with Boolean functions while studying sequential digital circuits. The problem of deriving algebraic representations for Boolean functions from their truth tables is related to the problem of simplifying digital circuits.[1]

Example 7-1—Truth Tables for a Boolean Function

Let f_1 be a Boolean function in four variables $\{v_1, v_2, v_3, v_4\}$ with the following truth table.

$$\begin{array}{l|cccccccccccccccc}
v_4 = & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
v_3 = & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\
v_2 = & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\
v_1 = & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\
\hline
f_1 = & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1
\end{array}$$

A quick inspection shows that this Boolean function can be represented by the expression $f_1 = v_3 + v_2 + v_1$. For a slightly more complicated example, consider the following.

[1] Muller was investigating applications of Boolean algebra to the problem of simplifying digital switching circuits when he discovered RM codes [Mul].

$$\begin{array}{l} v_4 = 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1 \\ v_3 = 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1 \\ v_2 = 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1 \\ v_1 = 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1 \\ \hline f_2 = 1\ 0\ 1\ 0\ 1\ 0\ 1\ 1\ 1\ 0\ 1\ 0\ 0\ 1\ 0\ 0 \end{array}$$

The reader may wish to verify that this Boolean function can be expressed as $f_2 = v_3 v_2 v_1 + v_4 v_3 + v_1 + 1$. ■

In Example 7-1 we have adopted a convention that will be maintained throughout the rest of the chapter. When viewed as the radix-2 representations for the integers $\{0, 1, 2, \ldots, 2^m - 1\}$, the columns of the truth table are seen to run in increasing order from left to right. The most significant bit of the binary expansion (the first row of the table) corresponds to the variable v with the largest subscript. This convention allows us to unambiguously associate each Boolean function f with a unique binary vector $\mathbf{f}$. $\mathbf{f}$ is simply the bottom row of the truth table for f. For the above example we have the following.

$$\mathbf{f}_1 = (0110100101101001)$$

$$\mathbf{f}_2 = (1010101110100100)$$

Since $\mathbf{f}$ is binary with length 2^m, there must be 2^{2^m} distinct Boolean functions in m variables. Under coordinate-by-coordinate binary addition of the associated vectors, the Boolean functions form the vector space V_{2^m} over GF(2).

Let the set M consist of all Boolean functions in m variables that can be represented by a single monomial term. We need not consider squares and higher-order powers of the individual variables, for v_i and v_i^2 represent the same Boolean function. M thus consists of the Boolean function 1 and the products of all combinations of one or more variables in the set $\{v_1, v_2, \ldots, v_m\}$.

$$M = \{1, \ldots, v_m, v_1 v_2, \ldots, v_{m-1} v_m, v_1 v_2 v_3, \ldots, v_{m-2} v_{m-1} v_m, \ldots, v_1 v_2 \cdots v_m\}$$

Since the Boolean functions in M are linearly independent, it follows that the vectors with which they are associated are also linearly independent. There is thus a unique Boolean function f for every vector $\mathbf{f}$ of the form

$$\mathbf{f} = a_0 \mathbf{1} + \cdots + a_m \mathbf{v}_m + a_{12} \mathbf{v}_1 \mathbf{v}_2 + \cdots + a_{12\ldots m} \mathbf{v}_1 \mathbf{v}_2 \cdots \mathbf{v}_m \qquad (7\text{-}1)$$

Since there are a total of 2^{2^m} such vectors, the Boolean functions in M form a basis for the vector space of Boolean functions in m variables. We now have sufficient machinery at our disposal to define Reed-Muller codes.

Definition 7-1—Reed-Muller Codes

The binary Reed-Muller code $\mathfrak{R}(r, m)$ of order r and length 2^m consists of the vectors $\mathbf{f}$ associated with all Boolean functions f that are polynomials of degree less than or equal to r in m variables.

Example 7-2—$\mathfrak{R}(1,3)$: The First-Order RM Code of Length 8

The monomials in three variables of degree 1 or less are $\{1, v_1, v_2, v_3\}$. Each of these monomials is associated with a vector as shown below.

$$\begin{aligned}
\mathbf{1} &= (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1) \\
\hline
\mathbf{v}_3 &= (0\ 0\ 0\ 0\ 1\ 1\ 1\ 1) \\
\mathbf{v}_2 &= (0\ 0\ 1\ 1\ 0\ 0\ 1\ 1) \\
\mathbf{v}_1 &= (0\ 1\ 0\ 1\ 0\ 1\ 0\ 1)
\end{aligned}$$

The code words in $\mathfrak{R}(1,3)$ consist of the 16 distinct linear combinations of these vectors. Since the four vectors form a basis set for $\mathfrak{R}(1,3)$, we can employ them as the rows of a generator matrix.

$$\mathbf{G} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$\mathfrak{R}(1,3)$ has length 8, dimension 4, and minimum distance 4. It is thus single-error-correcting and double-error-detecting.

This generator matrix may look vaguely familiar. It is also the parity-check matrix for the (8, 4) extended Hamming code (see Ex. 4-8). First-order Reed-Muller codes are the duals of extended Hamming codes. ■

Example 7-3—$\mathfrak{R}(2,4)$: The Second-Order RM Code of Length 16

The monomials in four variables of degree 2 or less are as follows.

$$\{1, v_1, v_2, v_3, v_4, v_1v_2, v_1v_3, v_1v_4, v_2v_3, v_2v_4, v_3v_4\}$$

The binary vectors associated with these functions are shown in Figure 7-1.

$$\begin{aligned}
\mathbf{1} &= (1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1) \\
\hline
\mathbf{v}_4 &= (0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 1\ 1\ 1\ 1) \\
\mathbf{v}_3 &= (0\ 0\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1) \quad 2 \\
\mathbf{v}_2 &= (0\ 0\ 1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1) \\
\mathbf{v}_1 &= (0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1) \\
\hline
\mathbf{v}_3\mathbf{v}_4 &= (0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 1\ 1) \\
\mathbf{v}_2\mathbf{v}_4 &= (0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 1\ 1) \\
\mathbf{v}_1\mathbf{v}_4 &= (0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 1\ 0\ 1\ 0\ 1) \\
\mathbf{v}_2\mathbf{v}_3 &= (0\ 0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 1) \\
\mathbf{v}_1\mathbf{v}_3 &= (0\ 0\ 0\ 0\ 0\ 1\ 0\ 1\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 1) \\
\mathbf{v}_1\mathbf{v}_2 &= (0\ 0\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 1)
\end{aligned}$$

Figure 7-1. Basis Vectors for $\mathfrak{R}(2,4)$

$\mathfrak{R}(2,4)$ is a $(16,11)$ code. As in the previous example, this code has minimum distance 4. The $\mathfrak{R}(2,4)$ code, however, has a higher rate than the $\mathfrak{R}(1,3)$ code. ∎

In general the space of Boolean functions of degree r or less has as a basis all monomial functions of degree r or less. It is a simple matter to count the number of elements k in this basis set for a given r and m, and thus determine the dimension k of $\mathfrak{R}(r,m)$.

$$k = 1 + \binom{m}{1} + \binom{m}{2} + \cdots + \binom{m}{r} \tag{7-2}$$

The following theorem shows that $\mathfrak{R}(r+1, m+1)$ can be constructed from $\mathfrak{R}(r,m)$ and $\mathfrak{R}(r+1,m)$. It is useful in determining the minimum distance of RM codes. Note that given $\mathbf{x} = (x_0, \ldots, x_{n-1})$ and $\mathbf{y} = (y_0, \ldots, y_{n-1})$, $(\mathbf{x}|\mathbf{y})$ is defined to be the concatenation of $\mathbf{x}$ and $\mathbf{y}$ (i.e., $(\mathbf{x}|\mathbf{y}) = (x_0, \ldots, x_{n-1}, y_0, \ldots, y_{n-1})$).

Theorem 7-1

$$\mathfrak{R}(r+1, m+1) = \{(\mathbf{f}|\mathbf{f}+\mathbf{g}), \text{ for all } \mathbf{f} \in \mathfrak{R}(r+1,m) \text{ and } \mathbf{g} \in \mathfrak{R}(r,m)\}$$

Proof. All code words $\mathbf{c} \in \mathfrak{R}(r+1, m+1)$ are associated with Boolean functions $c(v_1, \ldots, v_{m+1})$ of degree $\le r+1$. Such functions can be rewritten as $c(v_1, \ldots, v_{m+1}) = f(v_1, \ldots, v_m) + v_{m+1} \cdot g(v_1, \ldots, v_m)$. f has degree $\le r+1$ and g has degree $\le r$, so the corresponding vectors $\mathbf{f}$ and $\mathbf{g}$ can be found in $\mathfrak{R}(r+1,m)$ and $\mathfrak{R}(r,m)$, respectively.

Let $f' = f(v_1, \ldots, v_m) + 0 \cdot v_{m+1}$ and $g' = v_{m+1} \cdot g(v_1, \ldots, v_m)$. The associated vectors have the form $\mathbf{f}' = (\mathbf{f}|\mathbf{f})$ and $\mathbf{g}' = (\mathbf{0}|\mathbf{g})$, and both are code words in $\mathfrak{R}(r+1, m+1)$. It follows that $\mathbf{c} = (\mathbf{f}|\mathbf{f}+\mathbf{g}) \in \mathfrak{R}(r+1, m+1)$. **QED**

Theorem 7-2

The minimum distance of $\mathfrak{R}(r,m)$ is 2^{m-r}.

Proof. We proceed by induction on m.

For the case $m = 1$, $\mathfrak{R}(0,1)$ is the length-2 repetition code with $d_{\min} = 2 = 2^{(1-0)}$. $\mathfrak{R}(1,1)$ consists of all 2-tuples and thus has $d_{\min} = 1 = 2^{(1-1)}$.

Assume that, up to some m and for $0 \le r \le m$, the minimum distance of $\mathfrak{R}(r,m)$ is $2^{(m-r)}$. We now show that the minimum distance of $\mathfrak{R}(r, m+1)$ must then be $2^{(m-r+1)}$. Let $w(\mathbf{c})$ be the weight of $\mathbf{c}$ and let $d(\mathbf{c}_1, \mathbf{c}_2)$ be the Hamming distance between $\mathbf{c}_1$ and $\mathbf{c}_2$.

Let $\mathbf{f}$ and $\mathbf{f}'$ be in $\mathfrak{R}(r,m)$ and $\mathbf{g}$ and $\mathbf{g}'$ in $\mathfrak{R}(r-1,m)$. Applying Theorem 7-1, $\mathbf{c}_1 = (\mathbf{f}|\mathbf{f}+\mathbf{g})$ and $\mathbf{c}_2 = (\mathbf{f}'|\mathbf{f}'+\mathbf{g}')$ must be code words in $\mathfrak{R}(r, m+1)$.

If $\mathbf{g} = \mathbf{g}'$, then $d(\mathbf{c}_1, \mathbf{c}_2) = 2d(\mathbf{f}, \mathbf{f}') \ge 2^{m-r+1}$ (twice the minimum distance of $\mathfrak{R}(r,m)$). If $\mathbf{g} \ne \mathbf{g}'$, then $d(\mathbf{c}_1, \mathbf{c}_2) = w(\mathbf{f}-\mathbf{f}') + w[(\mathbf{g}-\mathbf{g}') + (\mathbf{f}-\mathbf{f}')]$. Note that $w(\mathbf{x}+\mathbf{y}) \ge w(\mathbf{x}) - w(\mathbf{y})$, since the nonzero elements in $\mathbf{x}$ and $\mathbf{y}$ may not completely overlap. We thus have $d(\mathbf{c}_1, \mathbf{c}_2) \ge w(\mathbf{f}-\mathbf{f}') +$

$w(\mathbf{g}-\mathbf{g}') - w(\mathbf{f}-\mathbf{f}') = w(\mathbf{g}-\mathbf{g}')$. Since $(\mathbf{g}-\mathbf{g}')$ must be a code word in $\mathfrak{R}(r-1,m)$, $d(\mathbf{c}_1,\mathbf{c}_2) \geq 2^{m-r+1}$. The result follows. **QED**

Table 7-1 contains the length n, dimension k, and minimum distance d_{min} of several RM codes.

TABLE 7-1. Several $\mathfrak{R}(r,m)$ codes expressed as (n,k,d_{min})

	$m =$	2	3	4	5	6	7
$r = 0$		(4,1,4)	(8,1,8)	(16,1,16)	(32,1,32)	(64,1,64)	(128,1,128)
1		(4,3,2)	(8,4,4)	(16,5,8)	(32,6,16)	(64,7,32)	(128,8,64)
2		(4,4,1)	(8,7,2)	(16,11,4)	(32,16,8)	(64,22,16)	(128,29,32)
3			(8,8,1)	(16,15,2)	(32,26,4)	(64,42,8)	(128,64,16)
4				(16,16,1)	(32,31,2)	(64,57,4)	(128,99,8)
5					(32,32,1)	(64,63,2)	(128,120,4)
6						(64,64,1)	(128,127,2)
7							(128,128,1)

The table illustrates a few interesting points. The codes $\mathfrak{R}(0,m)$ are repetition codes of length 2^m. On the other end of the spectrum, the codes $\mathfrak{R}(m,m)$ correspond to the vector spaces formed by all binary 2^m-tuples for all positive integers m. The codes $\mathfrak{R}(m-1,m)$ are simple parity-check codes, containing all binary 2^m-tuples of even weight.

The duals of Reed-Muller codes are also Reed-Muller codes, as shown in the following theorem.

Theorem 7-3—Dual Codes of Reed-Muller Codes

For $0 \leq r \leq m-1$, $\mathfrak{R}(m-r-1,m)$ is the dual code to $\mathfrak{R}(r,m)$.

Proof [Mac]. Consider a pair of code words $\mathbf{a} \in \mathfrak{R}(m-r-1,m)$ and $\mathbf{b} \in \mathfrak{R}(r,m)$. $\mathbf{a}$ is associated with a polynomial $a(x_1,x_2,\ldots,x_m)$ of degree $\leq (m-r-1)$, while $\mathbf{b}$ is associated with a polynomial $b(x_1,x_2,\ldots,x_m)$ of degree $\leq r$. The polynomial product ab has degree $\leq (m-1)$ and is thus associated with a code word $\mathbf{ab}$ in the parity-check code $\mathfrak{R}(m-1,m)$. $\mathbf{ab}$ has even weight, so the dot product $\mathbf{a}\cdot\mathbf{b} \equiv 0$ *modulo* 2. $\mathfrak{R}(m-r-1,m)$ is thus contained in the dual space of $\mathfrak{R}(r,m)$. However, since

$$\dim(\mathfrak{R}(r,m)) + \dim(\mathfrak{R}(m-r-1,m)) = 2^m$$

$\mathfrak{R}(m-r-1,m)$ must be the dual code of $\mathfrak{R}(r,m)$ by the dimension theorem (Theorem 2-9). **QED**

The first order Reed-Muller codes have a very simple weight distribution.

$$A_0 = A_{2^m} = 1, \qquad A_{2^{m-1}} = 2^{m+1} - 2$$

The weight distribution for the second-order codes is also known [see Mac, p. 443]. We can use these distributions in conjunction with the MacWilliams identity

(Theorem 4-11) to obtain the weight distributions for $\Re(m-2,m)$ and $\Re(m-3,m)$. Unfortunately the weight distribution (m a variable) is not known for any code of order r greater than 2.

7.2 THE REED DECODING ALGORITHM

In his 1954 paper, Reed described a multiple-error-correcting decoding algorithm for RM codes based on sets of parity-check equations [Ree1]. This decoding algorithm was the first nontrivial example of majority logic, or "threshold" decoding. In general, majority logic techniques are fast, but suboptimal. This is particularly true in the case of convolutional codes, where the difference in performance between majority logic decoding and Viterbi (maximum likelihood) decoding is substantial. For RM codes, however, majority logic decoding provides maximum likelihood, hard-decision decoding in an efficient manner.[2]

This section begins by demonstrating the application of the Reed decoding algorithm to a particular code, the $\Re(2,4)$ code in Example 7-3. A description of the general algorithm then follows.

The set of basis vectors for $\Re(2,4)$ (see Figure 7-1) can be divided into three groups. The first group consists of the vector $\mathbf{1}$, corresponding to the single monomial Boolean function of degree zero. The second group contains the vectors associated with the monomials of degree one, and the third group the vectors associated with monomials of degree two. The vectors in these three groups form the rows of a generator matrix for $\Re(2,4)$ as follows.

$$\mathbf{G} = \begin{bmatrix} \mathbf{1} \\ \hline \mathbf{v}_4 \\ \vdots \\ \mathbf{v}_1 \\ \hline \mathbf{v}_3\mathbf{v}_4 \\ \vdots \\ \mathbf{v}_1\mathbf{v}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{G}_0 \\ \hline \mathbf{G}_1 \\ \hline \mathbf{G}_2 \end{bmatrix} \tag{7-3}$$

$\mathbf{G}$ can be used to implement a nonsystematic encoder for $\Re(2,4)$ through simple matrix multiplication, as discussed in Chapter 4. Let the 11 bits in the message block $\mathbf{m}$ be written $\mathbf{m} = (m_0, m_4, m_3, m_2, m_1, m_{34}, \ldots, m_{12})$. The subscripts associate each message bit with a row in $\mathbf{G}$. $\mathbf{m}$ is encoded as follows.

$$\begin{aligned} \mathbf{c} &= (c_0, c_1, \ldots, c_{15}) \\ &= m_0\mathbf{1} + m_4\mathbf{v}_4 + \cdots + m_1\mathbf{v}_1 + m_{34}\mathbf{v}_3\mathbf{v}_4 + \cdots + m_{12}\mathbf{v}_1\mathbf{v}_2 \qquad (7\text{-}4) \\ &= [\mathbf{m}_0 \mid \mathbf{m}_1 \mid \mathbf{m}_2] \begin{bmatrix} \mathbf{G}_0 \\ \hline \mathbf{G}_1 \\ \hline \mathbf{G}_2 \end{bmatrix} \end{aligned}$$

[2] For a thorough treatment of majority logic decoding of both block and convolutional codes, see [Mas1].

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Helsinki, Filand
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Agenda item:

Source: **Samsung**

Title: **Harmonization impact on TFCI and New Optimal Coding for extended TFCI with almost no Complexity increase (rev 1)**

Document for: **Proposal**

Abstract

TFCI code is very important because decoder depends on the rate information which was carried by TFCI bits. So, TFCI decoding fails, whole decoding also fails. Therefore using a good code for TFCI is very important. However, during studies on Harmonzation impact on TFCI, we found some problems. The current coding scheme for extended TFCI is not optimal at all, so there is considerable performance degradation. Based on this observation, we propose new optimal coding scheme for extended TFCI with almost no complexity increase because we reuse inverse hadamard transform (IHT). Moreover, this code can be generated by natural and simple extension of the current (32,6) TFCI code.

Current Coding Scheme for TFCI

In this section, the current coding scheme is described.

For 6bit TFCI case, the current coding scheme is as following .

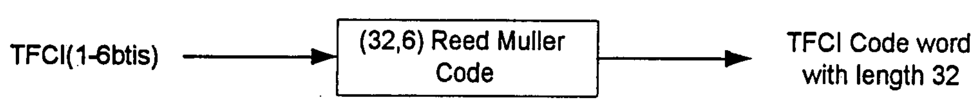

Fig1. The current coding scheme for 6 bit TFCI case

Mapping of the TFCI bits to the code words is described in the following table.

Information bits	Code word
000000	$C_{32,1}$
000001	$\overline{C}_{32,1}$
000010	$C_{32,2}$
.....	.....
111101	$\overline{C}_{32,31}$

111110	$C_{32,32}$
111111	$\overline{C}_{32,32}$

Table 1. mapping of 6bit TFCI bits into codewords

For 7-10bit TFCI case, the current coding scheme is as following .

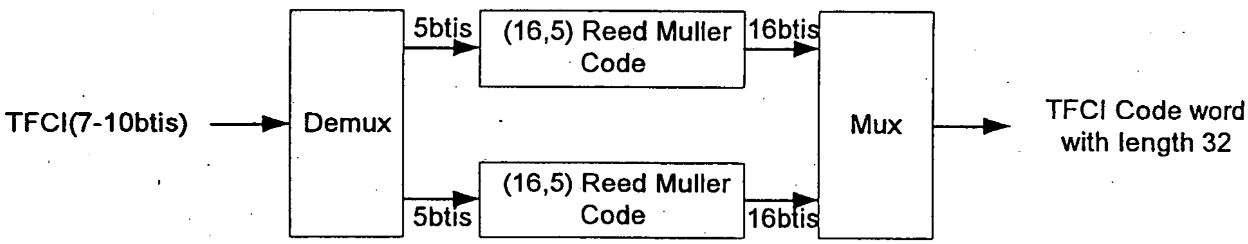

Fig2. The current coding scheme for 7-10bit TFCI case

Mapping of the TFCI bits to the code words is described in the following table.

Information bits	Code word
00000	$C_{16,1}$
00001	$\overline{C}_{16,1}$
00010	$C_{16,2}$
.....	.....
11101	$\overline{C}_{16,15}$
11110	$C_{16,16}$
11111	$\overline{C}_{16,16}$

Table 2. mapping of 7-10TFCI bits into Code words

Harmonization impact on TFCI coding and Problems of the current coding scheme for extended TFCI

As we see in figure in this section, there is no significant performance degradation by puncturing the current TFCI. The performance difference is about 0.1dB in AWGN, so we can say that there is no significant impact on TFCI by puncturing the current code. However, we see big performance difference between current (32,6) and (16,5) Reed Muller code. There is more than 0.8.dB performance difference in the operating point in AWGN. 0.8dB diffrence in AWGN is a big difference, and this difference must be bigger in fading environment. We should start to think if we can avoid this situation.

If we look at the paper [1], we can see the minimum dsitance of the code of length 32. Those values are summarized in the following table1.

	6 TFCI bits	7 TFCI bits	8 TFCI bits	9 TFCI bits	10 TFCI bits
Optimal minimum distance	16	14	13	12	12

Table 3. Optimal bound of the minimum distance for the code of length 32

Considering the table above, we can see that the current (32,6) Reed Muller code achieves the optimality because the minimum distance of the current (32,6) Reed Muller code is 16. However, the current coding scheme for (32,7-10) code is not optimal at all because the minimum distance of the current (16,5) Reed Muller code is 8. Therefore, we can expect a considerable performance degradation comparing with the optimal code. Furthermore, concatenating short code is a bad idea in terms of the performance.

Therefore, we should try to find a new code which can improve the performance for Extended TFCI, and does not require much complexity increase at the same time.

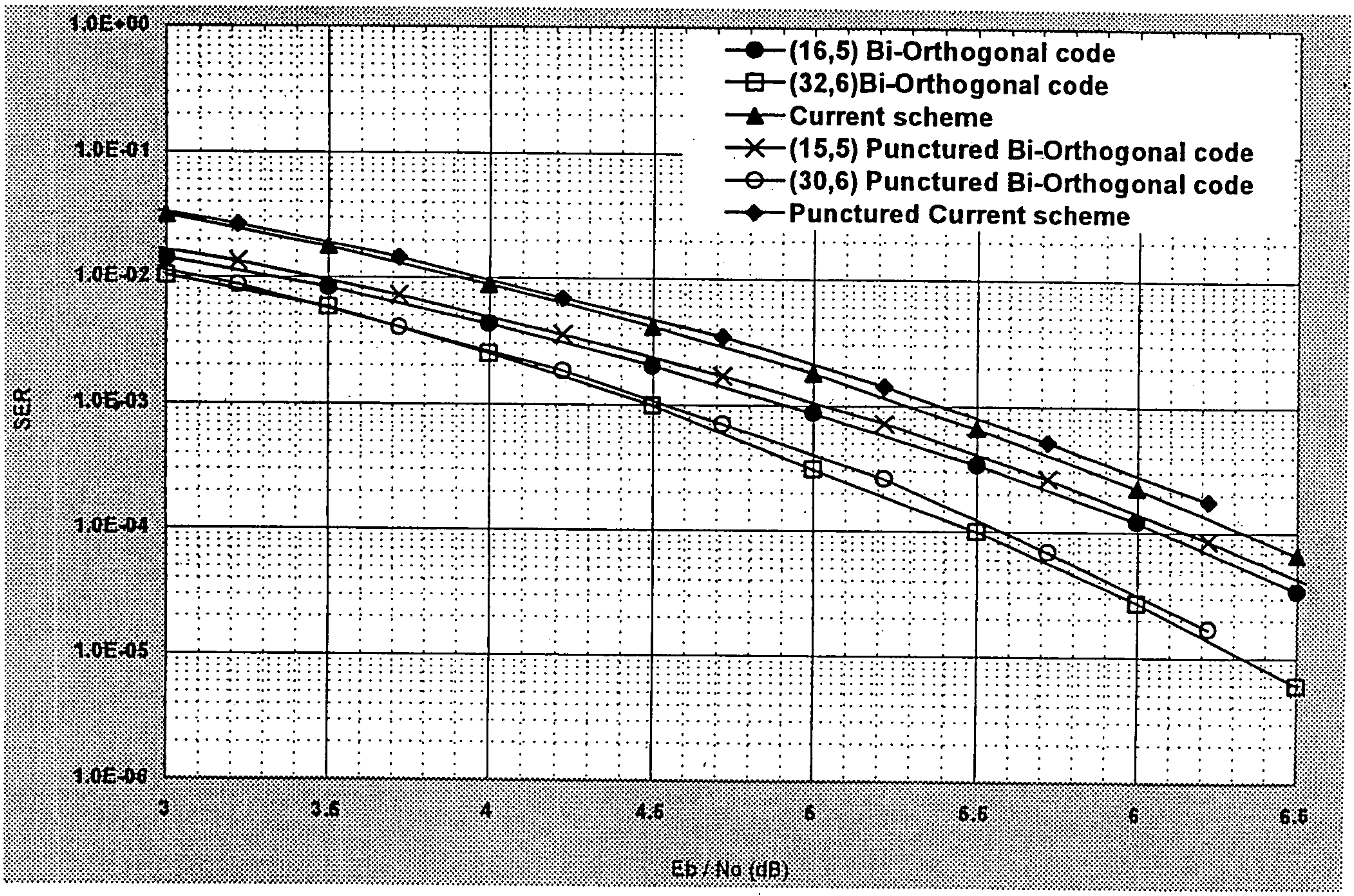

Fig 3 .SER performance of TFCI in AWGN

Proposed New TFCI Coding scheme

Based on Problems described in the previous section, we hope to have a better code than the current coding. Surprisingly, we can find a optimal code in the sense of a natural extension of the current (32,6) First Order Reed Muller code. Using sub-code of Second order Reed Muller code, we can achieve that goal. Second order Reed Muller code consists of codewords by adding some masks to the current First Order Reed Muller code.

Then, the number of mask is decided by the number of TFCI bits exceeding 6bit. In n bit TFCI case, $2^{n-6}-1$ masks is used for coding. For example, if we have 8bits for TFCI, then 3 masks are needed. To cover 10bit TFCI, 15 masks are needed. We can think the current (32,6) Reed Muller has a mask which consists of all zeros.

For 6-10bit TFCI case, the proposed coding scheme is as following .

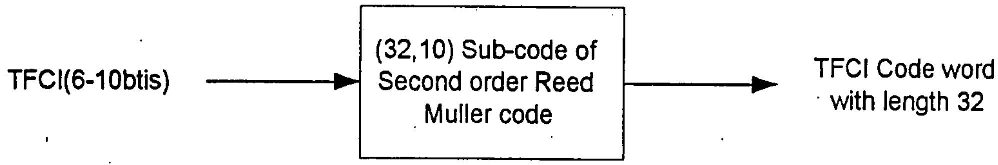

Fig 4. The Proposed coding scheme

Mapping of the TFCI bits to the code words is described in the following table.

Information bits	Code word	Information bits	Code word	Information bits	Code word
0000000000	$C_{32,1}$	0001000000	$M_1+C_{32,1}$	......	......
0000000001	$\overline{C}_{32,1}$	0001000001	$M_1+\overline{C}_{32,1}$	1111000000	$M_{15}+C_{32,1}$
0000000010	$C_{32,2}$	0001000010	$M_1+C_{32,2}$	1111000001	$M_{15}+\overline{C}_{32,1}$
.....	.....	......	......	......	......
0000111101	$\overline{C}_{32,31}$	0001111101	$M_1+\overline{C}_{32,31}$	1111111101	$M_{15}+\overline{C}_{32,31}$
0000111110	$C_{32,32}$	0001111110	$M_1+C_{32,32}$	1111111110	$M_{15}+C_{32,32}$
0000111111	$\overline{C}_{32,32}$	0001111111	$M_1+\overline{C}_{32,32}$	1111111111	$M_{15}+\overline{C}_{32,32}$

Table 4. Mapping of 6-10bit TFCI bits into codeword corresponding to the proposed scheme

We see that the new coding scheme for extended TFCI is made by just adding 15 masking functions to the current (32,6) Reed Muller code. The minimum distance of the new scheme is 12 as the optimal bound, and can be made as an extension of the current (32,6) Reed Muller code.

Encoder Sturcture

In this section , encoder structure of the new proposed scheme is described. In fact, all walsh code with length 32 is a vector space of dimension 5. So, there are 5 basis for vector space, for example, $W_{32,2}$, $W_{32,3}$, $W_{32,5}$, $W_{32,9}$, $W_{32,17}$. The current encoding structure is shown in the box of the figure below. The other is the addition because of the extension from (32,6) First Order Reed Muller code. As you see, additional complexity for this extension in the encoder is very minor, and we can also expect a simple decoding procedure because of this natural extension.

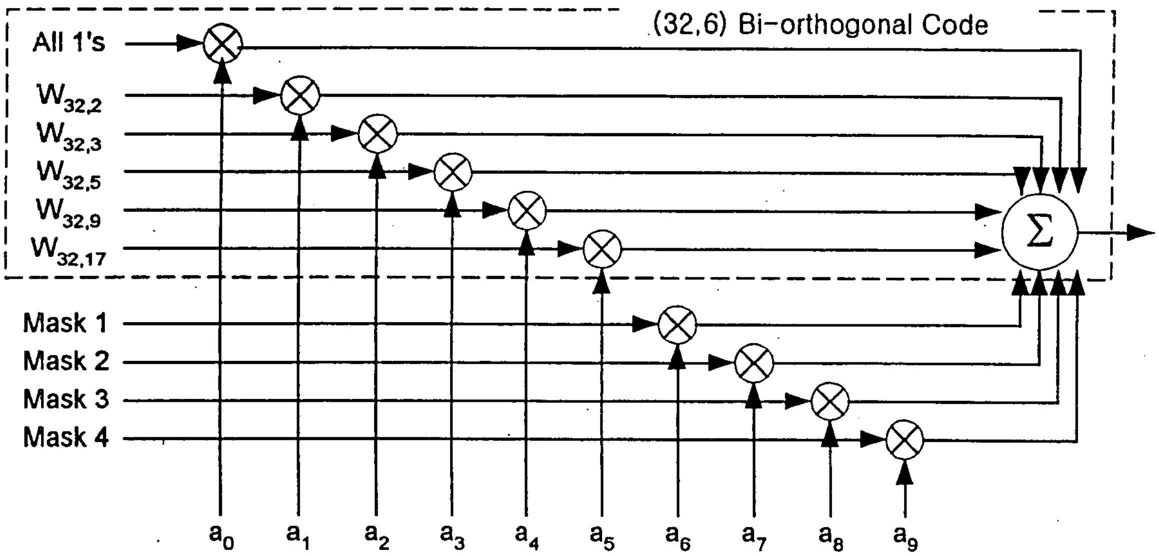

Fig 5 . Encoder structure

Actually, this basis is very meaningful, because we can make an encoder simply by linear operation. For (32,6) code case, if code index n is transferred into binary form $(a_0a_1a_2a_3 \ldots a_5)_2$, where a_i=0,1, then code becomes a a_5*$W_{32,17}$ + a_4* $W_{32,9}$ + a_3* $W_{32,5}$ + a_2* $W_{32,3}$ + a_1* $W_{32,2}$ + a_0*all 1's. Moreover, we select a mask set {0,M_1,M_2,M_3, ... ,M_{15}} in a vector space with demension 4, and we can choose a basis, M_1,M_2,M_3,M_4. Then, codeword set is a vector space of dimension 10 with $W_{32,2}$, $W_{32,3}$, $W_{32,5}$, $W_{32,9}$, $W_{32,17}$, M_1, M_2, M_3, M_4 , and all1's vector as basis. So, using the basis, the very simple encoder can be implemented, and the structure is as follows.

M1 = 00101000011000111111000001110111

M2 = 00000001110011010110110111000111

M3 = 00001010111110010001101100101011

M4 = 00011100001101110010111101010001

For example, when input TFCI bits $(0010010001)_2$, output coded symbol is

a_9*Mask4 + a_8* Mask3 + a_7*Mask2 + a_6 * Mask1 + a_5*$W_{32,17}$ + a_4*$W_{32,9}$+ a_3*$W_{32,5}$ + a_2*$W_{32,3}$ + a_1*$W_{32,2}$ + a_0*all 1's

= (00000001110011010110110111000111) + (00000000111111110000000011111111) +

(11111111111111111111111111111111)

= 11111110110011011001001011000111

Selecting masks is very important for good codeword. Actually, masks can be derived from Gold Code

Weight Distribution

Weight distribution and the minimum distance are the most important factor to determine the performance of the Linear Block code. In this section, we compare the weight distribution and minimum distance of the current coding scheme with that of proposed coding scheme in detail.

In TFCI 6bit case, The minimum distance is 16 and the weight distribution is shown in the following table.

Codeword Weight	Occurence
0	1
16	62
32	1

Table 5. The weight distribution of the current (32,6) bi-orthogonal code

The current scheme and the proposed scheme for Extended TFCI have the different minimum distance and weight distribution, and those values are shown in the table below. The difference of the minimum distance between the current scheme and the proposed scheme is 4. In Coding Theory, the difference 4 of the minimum distance in code length 32, is very high. We expect a considerable performance difference. The performance comparison between the current and proposed scheme is shown in next sections.

Current scheme	
Codeword Weight	Occurence
0	1
8	60
16	902
24	60
32	1

Proposed scheme	
Codeword Weight	Occurence
0	1
12	240
16	542
20	240
32	1

Table 6. Comparison of weight distribution of the current & proposed scheme for 7-10bit TFCI case

Performance

In this section, we show the comparison of the performance for 3 coding schemes by the simulation in AWGN channel and fading channels. The compared 3 coding schemes are as follows.

1. New proposed sub-code of Second order Reed Muller code

2. Current coding scheme ((16,5) x 2) for the extended TFCI bit

3. Single (16,5) Bi-orthogonal Code

In AWGN, new proposed Sub-code of Second order Reed Muller code has about more than 0.6dB as a coding gain compared with the current scheme. And, in fading channel with vehicular speed 30km and no power control, new proposed Sub-code of Second order Reed Muller code has about 3.5dB coding gain compared with the current scheme. This is the tremendous gain to consider the change of the current Extended TFCI coding scheme. This new code gives us a great coding gain, and does not require much complexity increase at the same time because of natural extension of the current code. The complexity will be explained in next section.

AWGN Channel

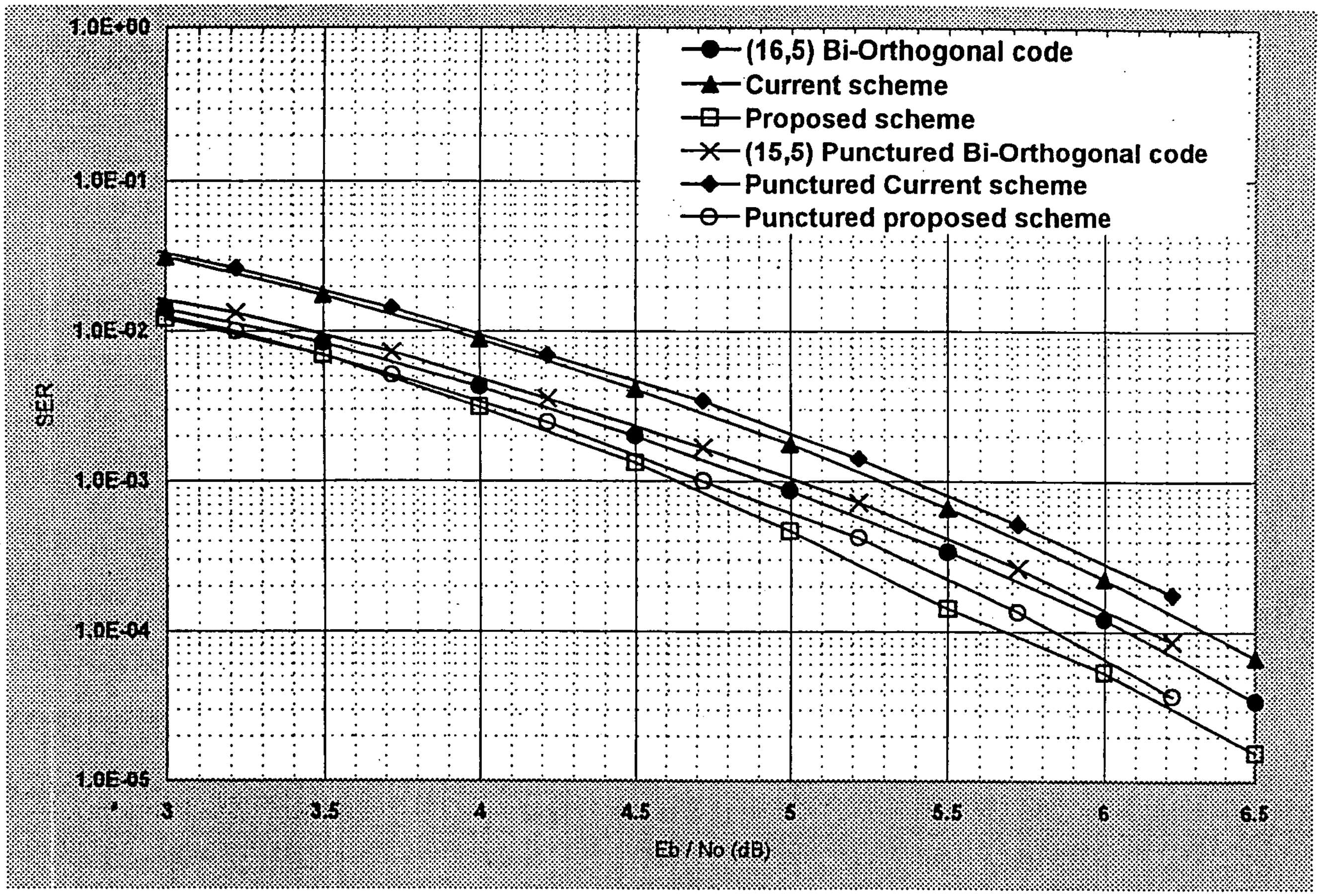

Fig 6. Performance curve in AWGN channel

Fading Channel

- JTC Model
- Vehicular Speed : 30Km
- No power control
- ideal estimation
- 1-path
-

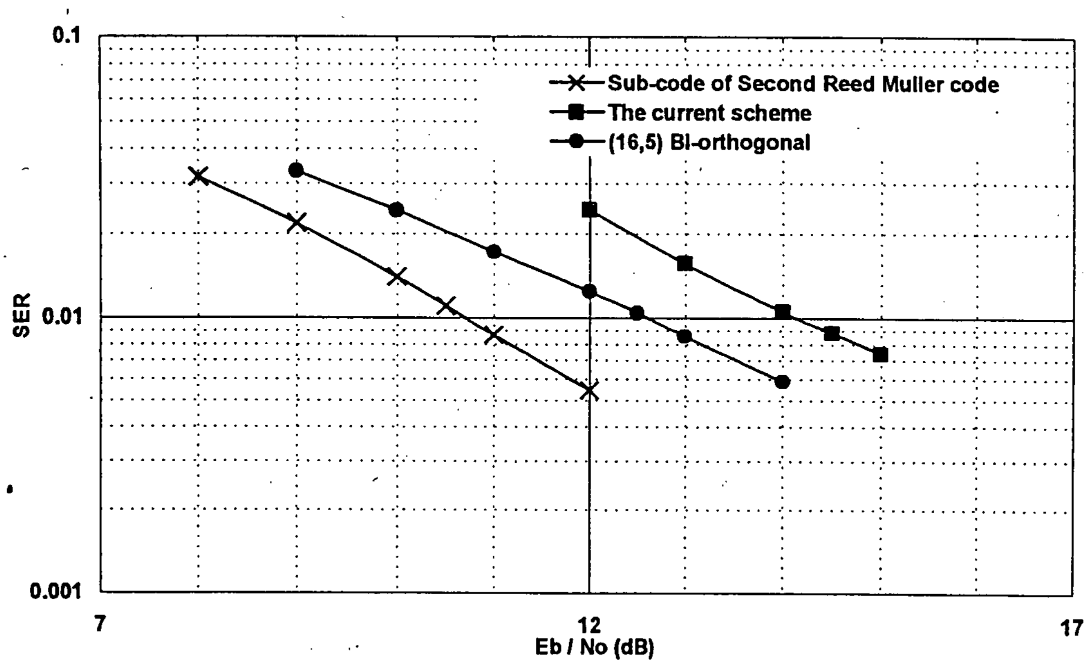

Fig 7. Performance curve in Fading channel with vehicular speed 30km

More Simulation results

In this section and next section, we run more simluations in various situations.

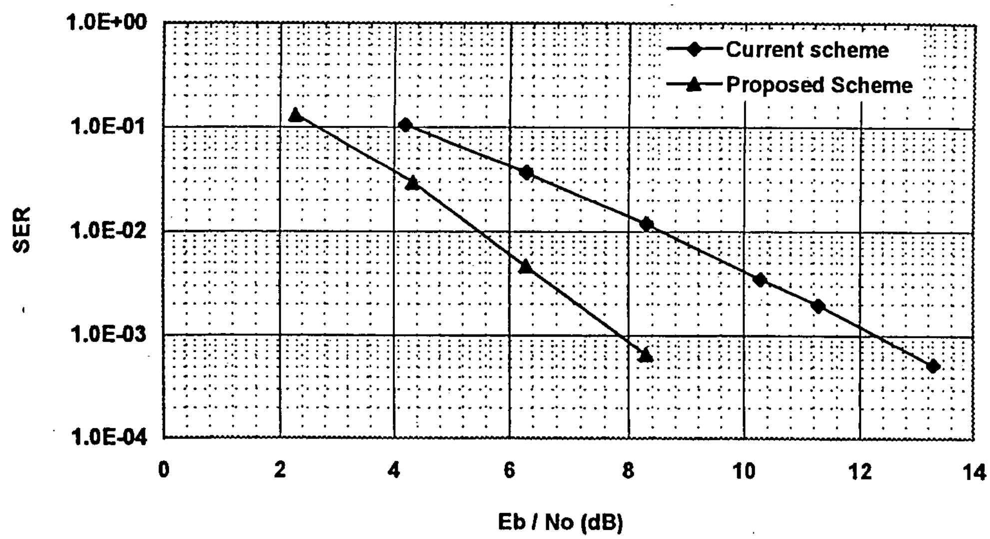

Fig 8. Performance curve in 1-path fading channel with power control and vehicular speed 30km/h

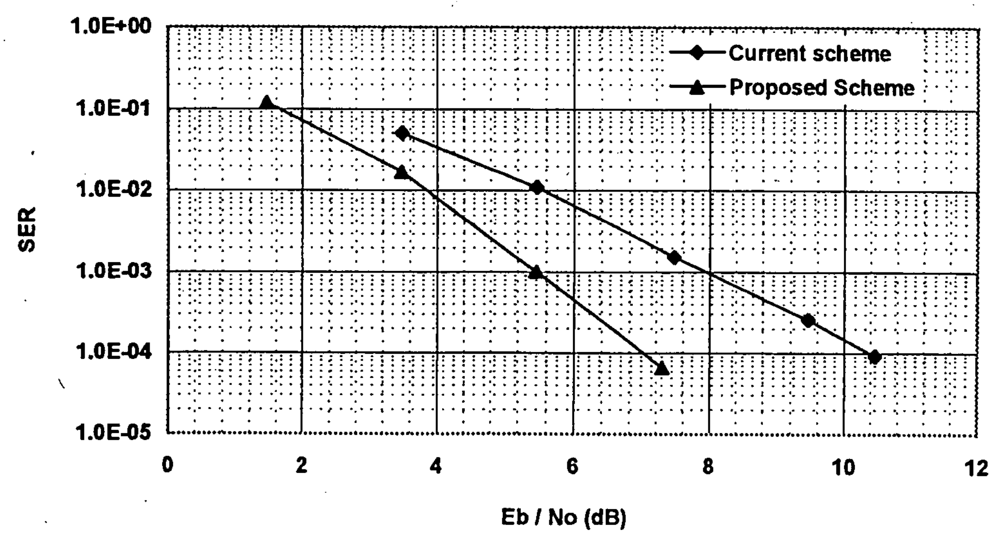

Fig 9. Performance curve in 2-path fading channel with power control and vehicular speed 30km/h.

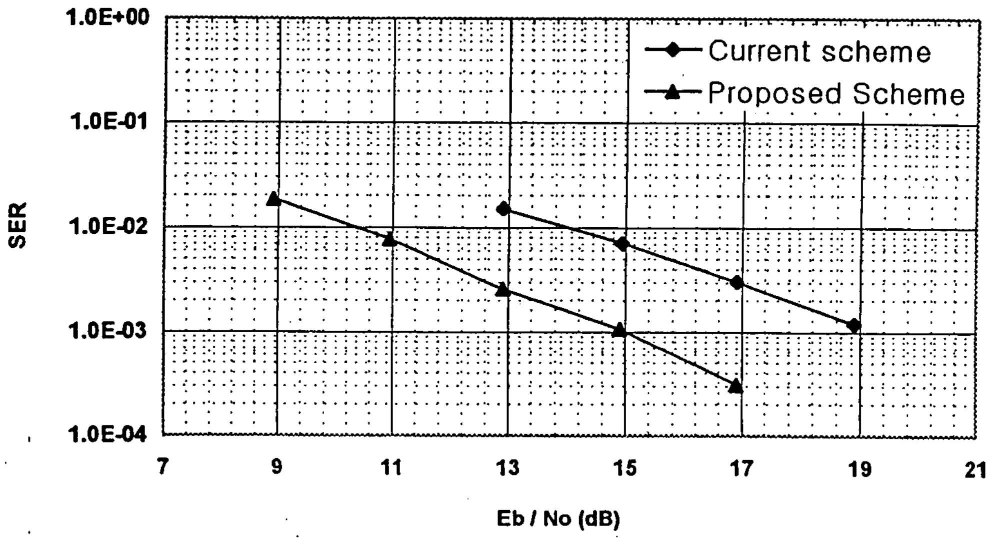

Fig 10. Performance curve in 1-path fading channel with no power control and vehicular speed 30km/h.

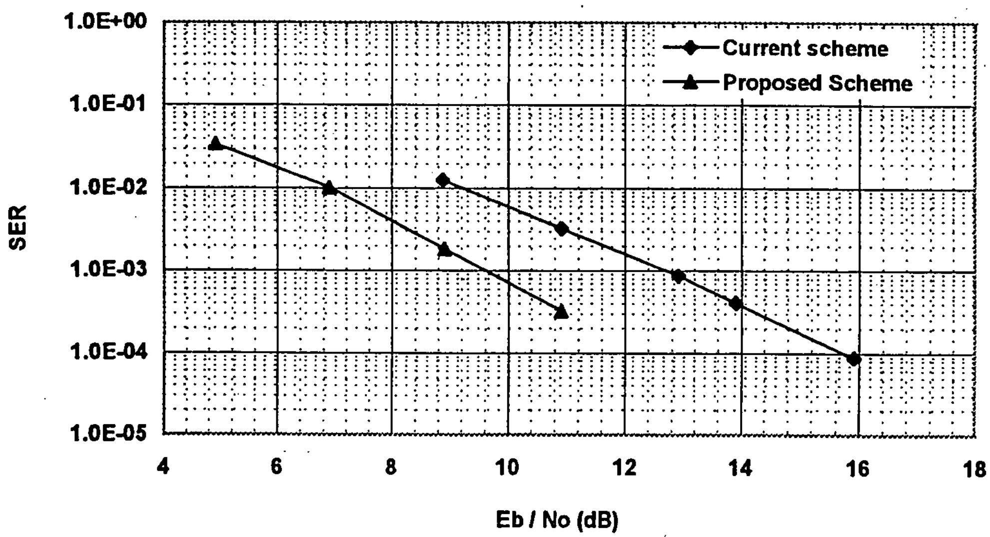

Fig 11. Performance curve in 2-path fading channel with no power control and vehicular speed 30km/h.

Consideration on 7-9 bits TFCI

In current specification, there is an algorithm to enhace gain when we only have from 7 to 9 TFCI bits. So we need to investigate these cases too.

We know that the gain comes from the reduction of signal constellation. Therefore, that algorithm also can be applied to new proposed scheme, and both schemes have some performance improvement. But we are not sure if they will achieve the same amount of performance improvement. If there is the performance difference in these cases, then the case of 7 bit TFCI will be the most significant case. So we run some simulation for 7bit TFCI.

Following figure shows the performance difference between the current scheme and new proposed scheme when we only have 7 bit TFCI. We can see that both schemes achieve the performance improvement comparing with 10 bit TFCI case, but the amount of difference is kept almost the same. Therefore, we can say there is the same gain even when we have 7 –9 bits TFCI.

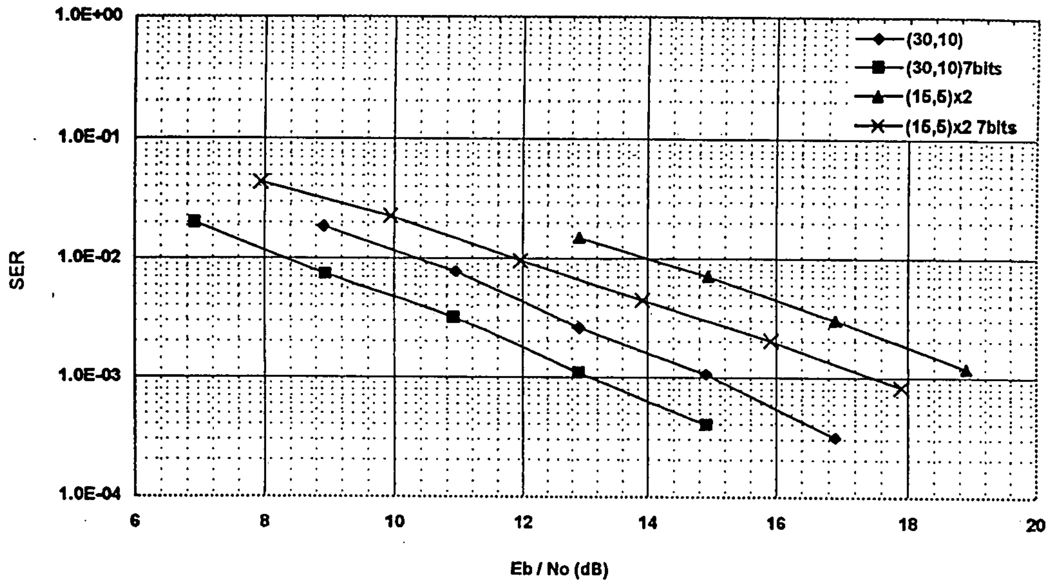

Fig 12. Performance in 1-path fading channel with no power control and vehicular speed 30km/h.

Consideration on Complexity and Decoder Structure

In this section, we will describe the decoding structure correspoding to the encoding structure in the previous section. For decoding, we can reuse the fast hadamard transform for current (32,6) First order Reed Muller code. The decoding structure is as follows.

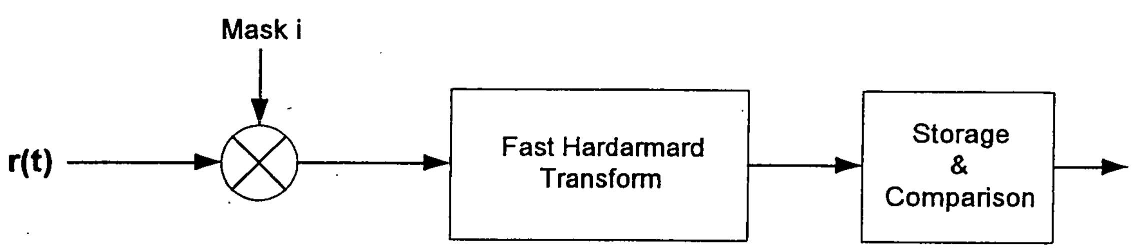

Fig 13. Decoder Structure

In the figure, when we recieve the signal **r(t)**, we multiply all possible mask with the recieved signal, and perform the fast inverse hadamard transform 15times or less iteratively. Then, the decoding complexity is not increased much because we reuse the current Hadamarad Transform block, but the decoding delay is increased about 16times. But this increase of decoding time is not matter comparing with other process for demodulation. If we assume a reuse of the current Hadamard Transform, then it needs about 64 cycles to finish to decode 32 length Hadamard, So for the decoding of new proposed scheme, it needs about 64*16 cycles. If we have a hardware operating with 70 MHz clock, then decoding delay for the current scheme is about 0.9μs and it for new coding is about 14.6μs. This decoding time delay is no problem at all for the real-time implmentation.

Conclusion

During studies on Harmonization impact on TFCI, we found some performance problem in the extended TFCI coding. The current coding scheme is not optimal at all, and too far from optimal. Considering the importance of TFCI because of big influence on link performance, we need to have a good code. In this proposal, we proposed new optimal TFCI coding which achieves a big performance improvement (0.6 dB in AWGN and 3.5 dB in Fading). It also turns out that this new code can be generated by natural and simple extension of the current (32,6) First order reed Muller code, so there is no significant complexity increase to decode. So we strongly recommend to change the current Extended TFCI coding scheme to new proposed one. There is no reason not to use optimal code which does not require much complexity increase.

Reference

[1] : "An Updated Table of Minimum-Distance Bounds for Binary Linear Codes" – A.E. Brouwer and Tom Verhoeff, IEEE Transactions on Information Theory, VOL. 39, N). 2, March 1993

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RELATED PROCEEDINGS APPENDIX

There are no known decisions rendered by a court or the Board in any proceeding identified pursuant to paragraph (c)(1)(ii) of 37 C.F.R. 41.37.